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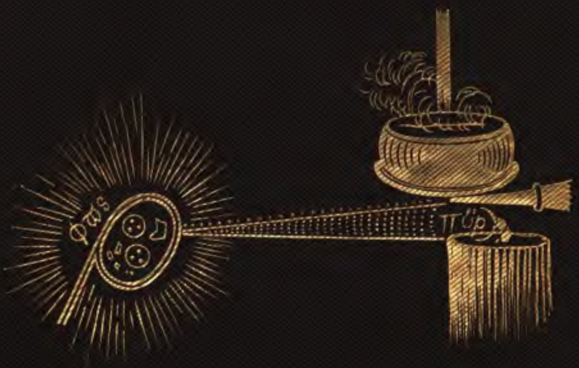

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THE BLOWPIPE IN CHEMISTRY, MINERALOGY, AND GEOLOGY.

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THE BLOWPIPE

IN

CHEMISTRY, MINERALOGY, AND GEOLOGY,

CONTAINING

ALL KNOWN METHODS OF ANHYDROUS ANALYSIS,
MANY WORKING EXAMPLES, AND INSTRUCTIONS FOR MAKING APPARATUS.

BY

LIEUT.-COLONEL W. A. ROSS, R.A. (Retired), F.G.S.
MEMBER OF THE GERMAN CHEMICAL SOCIETY,
AUTHOR OF "PYROLOGY;" "A MANUAL OF BLOWPIPE ANALYSIS," ETC.

With One Hundred and Twenty Illustrations by the Author

"AS THE EYE IS FRAMED TO SEE, AND THE EAR TO HEAR, SO IS THE MIND
OF MAN MADE TO EXPLORE."—*Tyndall.*

Capio Lumen

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An Herrn Bruno Kerl,

Profeſſor an der Königl. Bergakademie in Berlin, u.ſ.w.

Werther Herr Profeſſor,

Obgleich, im Angeſicht der Gegenſtandes und in Wirklichkeit ſo weit als das Verdienſt der Ausführung geht, dieſe kleine wiſſenſchaftliche Brochüre nur eine unbedeutende Arbeit iſt, ſo iſt der Gegenſtand, von dem dieſelbe handelt, meines Wiſſens die erſte practiſche Erörterung, welche in einer europaeiſchen Sprache veröffentlicht worden. Dieſer Gegenſtand—Anhydrous Thermo-Chemistry (Thermochemie waſſerfreier Verbindungen) iſt einer, den Sie beſſer als irgend ein Anderer kennen, von großer Wichtigkeit nicht nur für die Naturphiloſophie im Allgemeinen, als auch für viele andere Wiſſenſchaften und wiſſenſchaftlichen Künſte, wie metallurgiſches Probiren, pyrotechniſche Mineralogie, u.ſ.w.

Zu einer Zeit, als die Gelehrten meines Geburtslandes beinahe bis auf einen Mann meine langfortgeſetzten Arbeiten ignorirten und zurückwieſen, reichten Sie mir die Hand und zollten denſelben, eine große Genugthuung für mich, Ihren Beifall, wie Ihre Publicationen über meine Schriften in der Berg- und hüttenmänniſchen Zeitung darthun.

Ihre Erlaubniß, Ihnen hierfür dieſes kleine Werk zu widmen,

„Parvum, non parvi pignus amoris,"

gereicht mir zum größten Vergnügen und wird immer der Gegenſtand meiner wahren Dankbarkeit gegen Sie ſein.

Ihr

dankbarer und aufrichtigers

W. A. R.

PREFACE.

Of the determinative sciences, Anhydrous Analysis is the most simple and fascinating. Charmed with the rapidity of his results, eager with expectation, cheered in his labours by the general success of his experimental plans, the blowpipe analyst springs from theorem to problem,—from designs to facts,—with a facility of mind and hand unexampled in any other branch of chemical physics, until he obtains analytical results which might perhaps excite the generous envy of older and better chemists than himself.

That scientific Englishmen have begun to open their eyes to this undeniable truth is, I am happy and grateful to say, an accomplished fact. Soon may they learn the consequent fact that a knowledge of this science as it stands at present, will prove of commercial as well as educational importance, especially to our artisans, and tend to at least place them on a par with the most carefully trained of our Continental neighbours.

As regards my own experience, I can only say that this study has proved the solace and hope of a very chequered life, and that the retrospect of my humble labours in this new field is a constant and unfailing source of pleasure to me.

I will only add one fact here, as a proof of the encouragement the English worker may hope to receive from his munificent and appreciative countrymen, viz. that Mr. Hunt, of Messrs. Hunt and Roskell, the jewellers, of Bond Street, London, presented me, quite unsolicited, with a series of twenty packets of gems—rubies, sapphires, emeralds, &c.—for blowpipe analysis; the results of which I have given in a book on "Pyrological Mineralogy," which I trust will, before long, be permitted to see the light in the pages of my old and esteemed friend, the *English Mechanic and World of Science*, as was the case with this little work.

It will be found that, whenever desired by chemists, the definite borates described in this little work can as readily be obtained on a much greater scale, and weighed in the large assay balance.

W. A. R.

LONDON, W.
May, 1884.

INTRODUCTION.

In the spring of the year 1770, "Edward and Charles Dilly in the Poultry," London, published a small-octavo translation of Cronstedt's work on Mineralogy, containing, as an appendix, two very creditable wood engravings of a hitherto unheard-of chemical instrument, natural size, with pictures of some necessary apparatus; and an excellent little treatise entitled, "Description and Use of a Mineralogical Pocket Laboratory, and Especially the Use of the Blowpipe in Mineralogy."

The whole of these appendices were supposed to be the production of an Anglicised Swede, Gustav von Engeström, residing in London; a man evidently of great ability, although only an amateur, and possessing also considerable influence, for we see in Boswell's "Life of Johnson," that the brothers Dilly were at that time among the principal publishers in London.

But after careful examination of this matter, and collation of the various books and papers concerned, at the British Museum, the fact appears beyond all doubt, and can indeed be clearly proved, that the Swedish mine master, Von Svarb, was in reality the author of this treatise, and that a copy of it, made from dictation, was sent by Cronstedt surreptitiously to his friend

Von Engeström in London, to be translated and published there after the death of Von Svarb; accordingly, Von Svarb having died in 1769, the English translation of Cronstedt's "Essay" with the appendix consisting of poor Von Svarb's immortal blowpipe work under the above inviting title, and over the name of Von Engeström, came out in London in 1770.

Dilly's shop, therefore, may be considered the *birth-place* of descriptive *Blowpipe Analysis*, for although Von Svarb had nearly forty years before invented the chemical blowpipe, and Cramer had partly described its use with that of borax as a reagent, in a Latin treatise on "Assaying" published (at Leyden) in 1741, all record of the former's work has been buried in the archives of the Stockholm Academy of Science; whilst the description of the latter goes little further than that of the English Boyle in 1660, which only shows how "to melt small pieces of metal" with it.

It seems to me a melancholy fact to contemplate, that London, having thus been the parent of the "Poor-Man's Chemistry," "The Chemistry (*par excellence*) of the Microscope," and of "The Mineralogical Pocket Laboratory," should have not only repudiated her fortunate initiation of this important science, but should have used all the power and influence of her many distinguished chemists to crush it and put it down.*

With the sole exception of Faraday, no distinguished British chemist has done more than merely mention the blowpipe, as a useful but not indispensable laboratory drudge, compelled to answer chemical qualitative inquiries in certain formulæ, prescribed by the results of "wet" methods; whilst the work of the only original English writer on Blowpipe Analysis—the late J. J. Griffin—has been actually swallowed bodily as regards some of his inventions—*e.g.* the method of making charcoal paste with rice water—without any acknowledgment at all, in the later editions of Plattner's work, after Plattner's death.

---

* I understand that "The City and Guilds of London Institute" have quite recently, by the advice of an irresponsible chemist, cut out "Blowpipe Analysis," as worthless, from their *Curriculum*. It is still utterly untaught at "The Royal School of *Mines*"!

Having had now twenty-five years' experience in this matter, the latter half of which has been obtained in working upon the system devised by myself, I have carefully prepared this treatise, with the view of showing the student how to *teach himself* the science of Anhydrous Analysis, and its useful application to Mineralogy, &c., with special advice as to how and where the student (whom I assume to be an ordinarily intelligent town artisan of any of our large cities, without any greater knowledge of chemistry than can be acquired in these pages) can procure the material upon which and with which he is to work, at the *least possible price.* For instance, I purchased only the other day, at one of the "old curiosity shops" which swarm in the streets of London, a couple of old agate brooches without setting, for the economical sum of 2d. each; and a pair of polished agates is a very important item in blowpipe apparatus.

I shall commence by first showing him how to make his own apparatus, or adapt well-known articles to his purposes, with the prices of the materials he requires, and I shall then go on at once to examinations of the commonest minerals and rocks—such, for instance, as he may find specimens of in the public roads—by means of the most simple reagents, for it will not be necessary to trouble him with the expensive and recondite means of obtaining the reactions of chemically pure oxides, a table or list of which shall be here given for his guidance.

After this, he shall be led to the more elaborate analysis of minerals containing four or five oxides, as *Labradorite*, each of which will have to be isolated so as to be determined by the blowpipe beyond all doubt. It will then, I hope, be manifest to the student that he shall be able, by means of his lamp and blowpipe, after a patient and persevering utilisation of his leisure time in this most fascinating study, to literally excel the miracles fabulously performed by "Aladdin and his Wonderful Lamp." He shall use it as a key of fire to unlock the secret and solid stores of nature; as an instrument of torture, to force her to confess how she colours her amethysts, emeralds, and sapphires;* as a "pencil of light," wherewith to trace, in imperishable records, and with electric rapidity, the precise composition alike of her soft, sulphurous ore, or her adamantine corundum.

The student who is somewhat of a proficient in Blowpipe Analysis, can commence his work with Chapter V., page 60, making an especial study of Tables III., IV., V., and VI.; and by procuring from a mineralogical friend, unlabelled, but known powders for his investigation after the manner of the analyses detailed in Chapters X., XI., and XII.

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* *Vide Berg und Hüttenmännische Zeitung*, xli. Jahrgang, No. 48, s. 509.

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THE BLOWPIPE

IN CHEMISTRY, MINERALOGY, AND GEOLOGY.

◆

CHAPTER I.

ON THE MANUFACTURE OF BLOWING APPARATUS.

BLOWPIPE analysis having been shown in the "Introduction" to have been born an English science, and, indeed, "within hearing of Bow bells," I may be excused for describing its general objects to Englishmen in the very words of its founder, VON SVARB (printed in italics in the original): "*This art consists in a method of making mineralogical experiments upon a piece of charcoal with the concentrated flame of a candle blown through a blowpipe.*"

In order to "blow this flame," you must have a constant blast, and this blast may be created by three simple means, as follow:—

1. *A Mouth-blower*, or common blowpipe, in employing which the lungs are used as bellows, and the cheeks as an air-reservoir.
2. *A Foot-blower*, from which the blast is created by air-pressure, caused by repeated strokes of a pair of bellows filling an elastic air-reservoir.
3. *A Hand-blower*, the same as (2), only smaller, placed upon the table instead of under it, and worked by hand instead of foot.

Before proceeding to a description of the manufacture of these apparatus, let me here dispose of a remark of the great Swedish chemist, Berzelius, which is still maintained and put in practice by too many teachers and students of blowpipe analysis. After giving an account of various mechanical inventions to create a constant blast, Berzelius concludes: "I pass them by, since all these attempts prove that the inventors had no correct idea of the use of the blowpipe [Plattner and Harkort were among them!] and it may with propriety be said that they might as well have proposed to play upon a wind instrument with a pair of bellows."

Berzelius was not the first great man and really clever writer who has committed himself to a foolish statement, and the metaphorical illustration of his views, although not wanting in a certain "smartness," is especially unfortunate nowadays, since the most beautiful "wind instrument" Europe possesses—the English or Wheatstone's concertina—*is* "played upon with a pair of bellows."

The fact is, that with greater air-pressure (or what is popularly called "a more powerful blast") the operator obtains, if the bulk of his lamp or gas-flame is duly proportioned, greater and more localised heat, and, therefore, better and more rapid results.

How to make a Mouth-Blower or Common Blowpipe.

Procure half a foot of thin but stout, ordinary brass tubing, about seven-tenths of an inch in diameter; and another 6-in. piece, a little smaller, so as to draw in and out of the former, and yet fit air-tight, like the tubes of a telescope. Now solder a round flat piece or disc of brass, a little thicker than that of which the tubes are composed, into one end of the wider tube, so as to close it air-tight. These are called the "body-tubes" of the blowpipe, and are thus made to draw out and in, partly for convenience in packing, and partly to suit exactly what is called the "focal distance" of the eyes of the worker, which differs slightly in every individual, and is liable to be modified by age, sickness, &c. Everyone's eyes see minute objects (small print for instance) best at a certain point in front of them, called their "focus," the space between this point and the pupil of the eye is called its "focal distance," and it therefore follows that, if a short-sighted person uses a blowpipe with long body-tube, or a far-sighted man a short-body tubed blowpipe, in neither case will the operator see properly the minute "reactions" going on in the "assay" or object upon which he is working.

We must now make the "jet" of our blowpipe—not quite so easy as making the body-tubes—but here is a picture of it (A, Fig. 1), the shape and about two-thirds the size it is required in reality to be, so that the student will have less difficulty. He will observe that it is also a tube of thin brass, but which tapers from a broader to a much narrower end, though not quite to a point. The dotted lines show where it is covered by the large body-tube of the blowpipe, across which it passes at right angles, about half an inch from the closed or soldered end above described; and the student will note that these dotted lines represent on this scale seven-tenths of an inch, or a space equal to the diameter of the larger body-tube, into which it must, of

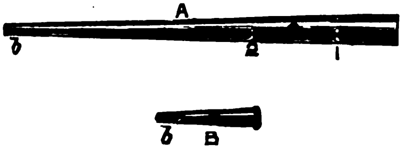


Fig. 1.

course, fit *air-tight*. The dark-shaded circle between the dotted lines is the air-hole for passage of the breath. B is the *nozzle*, which fits air-tightly, but without screwing, upon the narrow end (*b*) of the jet. *Its* narrow end (*b*) is solid as far as the dotted line, but bored *very* correctly by a hole through its centre, which a coarse needle should close, for the passage of the minute stream of air required. These little nozzles, made of brass, are, I believe, sold for 2d. or 3d. each; but they are best made of platinum, because in that case, when clogged with soot (as they unavoidably become after a time) they may be instantly cleaned before the blowpipe on charcoal; and all platinum articles which are sold by weight, only stand the purchaser in half the original cost, because Messrs. Johnson and Matthey, of Hatton Garden, London, purchase old platinum wire-ends, &c., for half-price of an equal weight of new articles.

We must now revert to the body-tubes again in order to finish our blowpipe. Having bored, with great correctness, two holes in the wider body-tube, of diameters corresponding respectively with the size of the jet at the dotted line 1 and 2, Fig. 1, and passed the jet through these holes so that it fills them air-tight, and stands out from the body-tube at right angles to it (Fig. 3), the workman now covers the narrow end of the jet with the nozzle (B), and fastens with waxed silk-thread over the broad end, one of those india-rubber bladders sold in the parks to children and nursery-maids for, I think, a halfpenny, but considerably reduced in size—C, Fig. 3. This is in order to make what I have called an "air-reservoir blowpipe;" but he should also make a little copper or brass stopper (or a bit of cork with sealing-wax might even do on an emergency), so as to fit air-tight into this broad end of the jet, thus enabling the whole, if preferred, or when necessary, to be used, as an ordinary blowpipe. All my artisan-student has now left to do is to make the "trumpet mouthpiece" (an invention of the celebrated German pyrologist Plattner) of wood, of the shape and size shown in Fig. 2, bored through as figured by the dotted lines, and having a little pasteboard valve (made by *nearly* cutting out a circular disc) glued on the bottom, as shown (open) at *v*. This mouthpiece must of course fit air-tight, and yet the student ought to be able to remove it when required. The valve may also be made by simply fastening a piece of oiled silk loosely over that end, so as to close the hole upon any pressure of air from the *inside*, but open it on receiving a blast from the mouth. Thus the air or breath cannot return into the operator's cheeks, but the more he blows after the elastic bladder is filled, the greater will be the air-pressure of the blast on the flame; and he may even increase this pressure by squeezing the bladder with his hand. It is obvious that no practice is required to use this blowpipe.

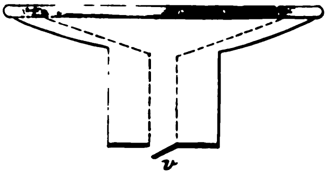


Fig. 2.

The "Air-reservoir Blowpipe" is now finished, and should present something of the appearance of Fig. 3, which is about half the natural size. The telescopic joint at *a* may be covered by a small piece of elastic tubing, which assists in keeping it perfectly air-tight, and also facilitates a good grasp of it by the right hand. The dotted lines show the distance which tube A generally projects into tube B. The instrument is packed by drawing out the two joints completely separate, taking out of its place the jet with its nozzle and windbag, folding the latter together in the shape of a small roll, and slipping them gently into the smaller body-tube A; A is then, with its contents, pushed again into tube B, but this time right up to the soldered end, so that the whole size and appearance is that of tube B.

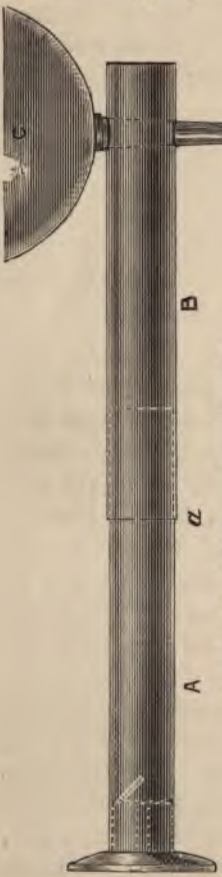


Fig. 3.—Ross's Air-reservoir Blowpipe.

This form of blowpipe can, as above mentioned, be used without the "air-reservoir" if required, or if the supply of elastic bags is exhausted, by simply stopping the broad end of the jet so that it is air-tight, and removing the throat-valve *v*; but the student can, if he prefers it, purchase one of the conical tinned and lacquered iron blowpipes called "Black's" (said to be the invention of the celebrated Edinburgh chemist Dr. Black) for, I believe, a shilling, and, of course, an air-bladder and mouth-piece with valve may easily be fitted on one of them (Fig. 20). There are numerous other kinds of ordinary mouth-blowpipes which need not be described here, as every shop keeping these articles has a stock of them. Of these by far the best is the one known as "Gahn's blowpipe

with Plattner's trumpet mouthpiece" (Fig 4), of which Fig. 5 is a modification proposed by me.

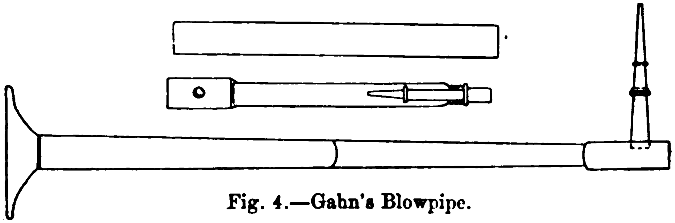


Fig. 4.—Gahn's Blowpipe.

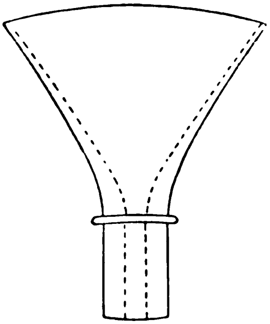
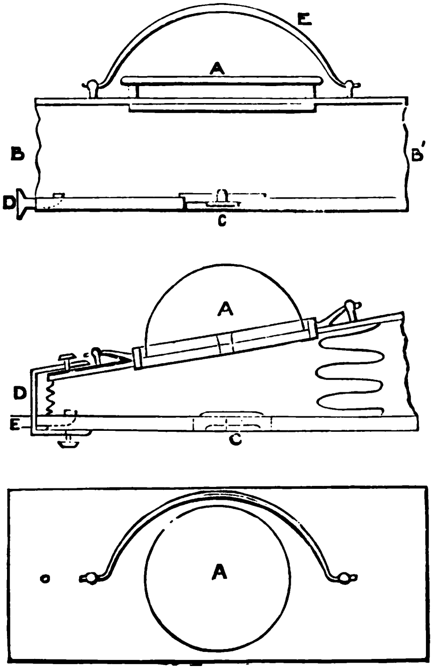


Fig. 5.—Plattner's Trumpet-Mouthpiece.

How to make a Foot-Blower.

Get a small pair of ordinary housemaid's hand-bellows (price 1s. 6d.); if thought too large, saw off both the handles, file or cut off about three inches of the iron nozzle, and apply one end of a piece of elastic tubing (price 7d. per yard) to the stump by means of a small angular glass or brass tube to lead it upwards; fix an ordinary goldsmith's curved blowpipe (price 6d.) in the other end of the tube, which should be sufficiently long to reach comfortably to your lamp on the table, and no longer. At any convenient position between these points you must fasten in the elastic tube a small elliptic india-rubber bag (Fig. 6), open at both ends (kept by all druggists), by means of two small pieces of glass tubing the requisite width, and a little fine wire strapping or waxed silk, to act as an air-reservoir. Now open the leather part of your bellows carefully on the side opposite the valve, and fix neatly down by means of small iron-wire pins on that inner side, a not too strong circular chair-cushion spring, so that when the bellows are pressed together the valve shall not be interfered with. The bellows being carefully and air-tightly closed again, with the spring inside, will now remain distended, and are to be placed on the floor near the worker's right foot, valve downwards. He will find such a foot or hand-blower almost

Fig. 6.



Figs. 7, 8, and 9.—Ross's Box Foot-blower.

indispensable in operations with boric acid, unless he is a first-rate user of the mouth-blower. Figs. 7, 8, and 9 represent a box for apparatus which can be used as a foot-blower. They require no description.

How to make a Leather Hand-Blower without Valve or Spring.

A (Fig. 10) is a plan of the two wooden circular frames belonging to this blower, *a* being the smaller frame, and *b* the larger one; the larger shaded circle is a hole cut in the upper smaller frame; the small shaded circle a hole in the under larger frame. B is a front elevation of *b*, showing a section of the windpipe as a dark-shaded circle, with an iron slot *c* underneath, for the head of a screw or nail fastened into the table, to keep the blower down when pulled upwards. C is a stereographic sketch of the hand-blower in position, *a* and *b* being the two wooden frames, with *d* an elastic air-reservoir covered by a hair-net, and *e* a blast-pipe with nozzle, which can, of course, be made any length convenient to the operator; *c* is the table-screw fitted into the slot above described, which Mr. J. T. Letcher thinks might be done away with, by weighting the inner side of the large wooden frame A with two pieces of lead; or the whole of its inner surface might be covered with a circular sheet of lead. This arrangement would not injure the table in any way, and would, I think, be sufficient to hold the blower down, making it a *little* heavier; but that is not of much consequence. *f, f, f* are pieces of elastic tubing, placed where convenient.

To use the machine, the smaller wooden frame is taken between the operator's thumb and second and third fingers; when the soft leather bag has been thus pulled out to the utmost extent, as shown in C, Fig. 10, the hole *a* is stopped air-tightly by the *first* finger, and the bag pressed firmly down, which motion has the effect

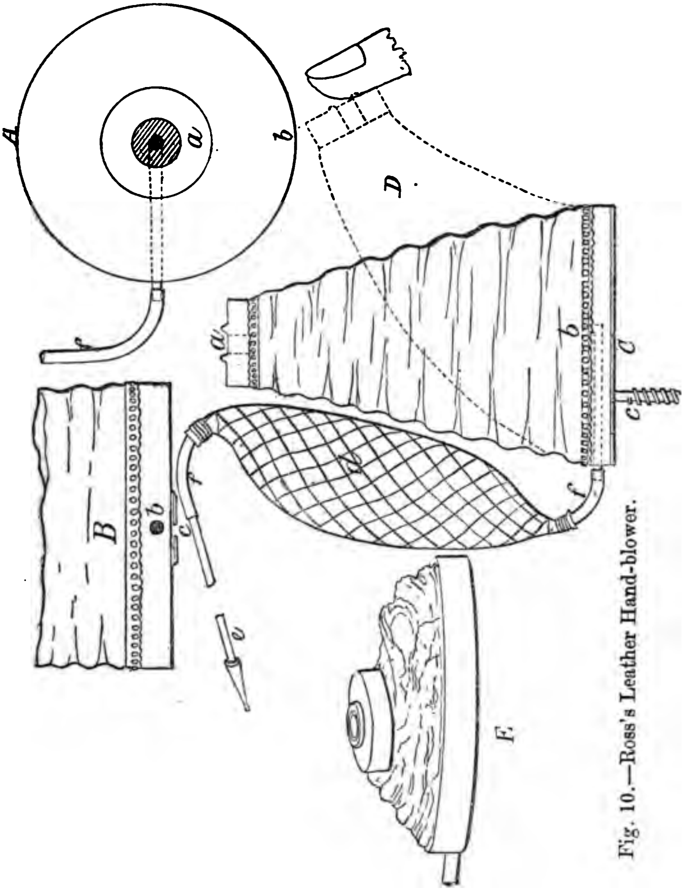


Fig. 10.—Ross's Leather Hand-blower.

of driving its contained air into the reservoir *d*, which is at once expanded, and exerts an amount of air-pressure upon the lamp-flame proportioned to its expansion. In pulling up the blower to renew the downwards stroke, the forefinger is raised from the hole *a*, thus acting as *the valve*, whilst the extremely slight muscular force of the arm required to pull up the soft leather bag, acts instead of the *steel spring*, which constitutes the chief expense of leather hand-blowers.

Mr. J. T. Letcher, of Truro, Cornwall, has been so kind as to make, at my request, a temporary but working specimen from the above sketch and description, of the cheapest possible materials; the air-reservoir and tube, *d, f*, Fig. 10, being made of one of those squeaking, elastic air-bladders sold in toyshops for one-halfpenny each. He will, no doubt, make others more complete and stronger than this, to any orders; and I am quite certain, from what I have seen of his work, that purchasers will be thoroughly satisfied with it, as being far more moderate in price, and yet quite as well finished as that of the best Freiberg makers. I have constituted him sole trade maker of this hand-blower (which would appear to be the cheapest leather one in existence), as well as of the whole of my pyrological apparatus.

The dotted lines surrounding D show another form of wind-bag, which, I think, would be an improvement, and not increase the price at all. E is a rough sketch of the blower made by Mr. Letcher, closed for packing. All Figs. are half the natural size.

Vulcanite Hand-Blowers.*

An extremely ingenious one is made by the above-mentioned gentleman. It is, in few words, the conversion of one of those white, vulcanite, children's air-balls, about the diameter of one's closed fist, sold in toyshops for 3d. or 4d. each, into a *blowpipe hand-*

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* Vulcanite blowers lose elasticity in a hot climate (as India).

blower (!), and a very efficient one Mr. Letcher has made of it.

Although, of course, such a blower would not be

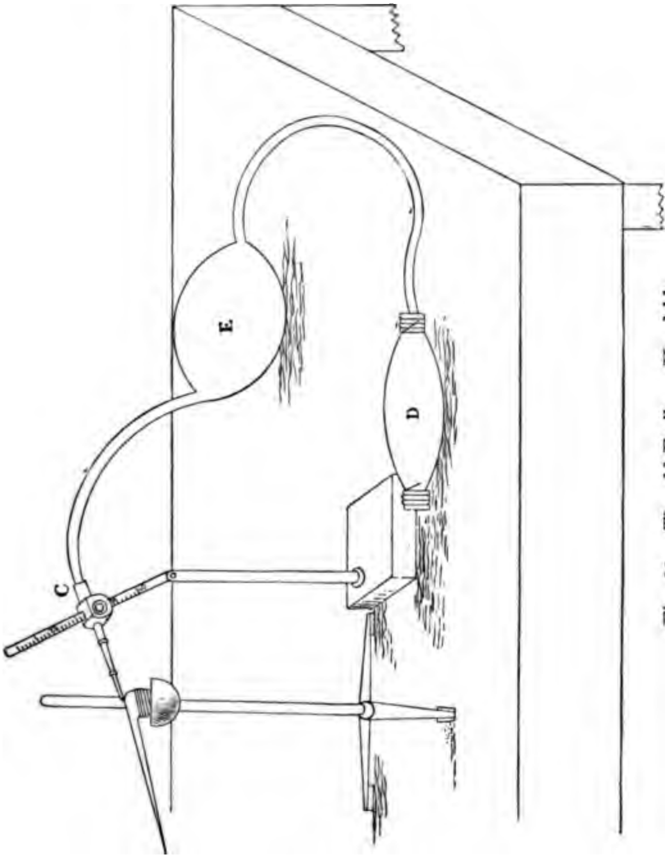

Fig. 11.—The old Freiberg Hand-blower.

expected to possess the power of leather bellows, the return of the elastic ball to a spherical shape after squeezing (which creates the atmospheric in-draught) being by no means so vigorous as the outwards force of a contained steel spring, or the muscular pulling open of hand (housemaid's) leather bellows, and consequently the pressure of indrawn air and then of expelled air being proportionately less; still, for ordinary purposes of blowpipe analysis—as *e.g.* the sublimation of volatile metals on aluminium plate, &c.—this cheap and most ingenious little hand-blower is really first-class.

The valves are placed in two small turned pieces of boxwood inserted into the poles of the little elastic air-globe, and an elastic air-reservoir, covered by a hair-net, is situated about halfway in a piece of vulcanised rubber tubing leading to the telescopic stand for the jet and nozzle, which are moved up, down, or sideways on a kind of universal joint, this stand being also, I believe, an invention of Mr. Letcher.

Fig. 11 represents the old Freiberg vulcanite blower, with stand and lamp. D is the bellows; E the air-reservoir, and C the jet. The upper limb of the stand was graduated by me to show the angle of depression.

Fletcher, of Warrington, makes beautiful little leather hand-blowers, Fig. 12. I shall conclude this chapter by quoting an account by the manufacturer, Mr. Newman (1816), of *Brooke's Piston Hand-blower*:—

"The instrument consists of a strong plate-copper box, perfectly air-tight, 3 in. in width and height, and 4 in. in length; a condensing syringe to force air into the box, and a stop-cock with jet at one end of it, to regulate the blast. The piston-rod of the condenser works through leather collars in the cap, which has an aperture in the side, and a screw connected with a stop-cock, which may again communicate with a jar, bladder, or gasometer, containing oxygen, hydrogen, or other gases. The use of the instrument is very simple. By a few strokes of the piston, air is thrown into the chamber, and forms a compressed atmosphere within. When the stop-cock is opened, the air expanding, issues out with great force in a small but rapid stream, which, when directed on the flame of a lamp, acts as the jet from a common blowpipe, but with more precision and regularity. . . . . These blowpipes are very portable, not liable to injury, and answer, I believe, the expectations of all who have tried them, and I have made many for different persons. The whole instrument, with lamp adapted to it, packs in a small box 6 in. long and 4 in. in width and height, and there is space enough left for other small articles."

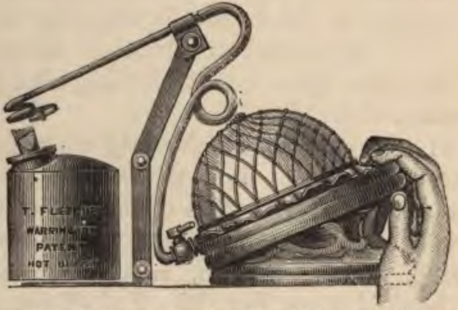

Fig. 12.—Fletcher's Leather Hand-blower and Lamp.

I have only to add that some later German and American writers on Blowpipe Analysis speak (in a rather sneering manner) of foot and hand-blowers as being "automatic" (Greek *automatos*, a self-moving machine), but I would, with all due deference, observe that they are no more *automatic* than a mouth-blower is, the only difference being that the former are worked by the muscles of the leg or arm, and the latter by those of the sides compressing the lungs, and of the cheeks.

CHAPTER II.

ON THE CONSTRUCTION OF PYROLOGICAL LAMPS—OIL, CANDLE, AND GAS.

HAVING considered in Chapter I. the best forms of Blowers, in studying Blowpipe Analysis, I must now ask my readers to give me for a time the whole of their attention and mechanical ingenuity while we devote an hour to a not less important matter: the construction of our fuel-burners or lamps. As inferred in the heading, pyrological fuel exists in three states or conditions—fluid, solid, and gaseous. In other words, as oil (for "spirit," *i.e.* alcohol, is useless in this relation), as a candle or melted fat, and as coal-gas; and it will be obvious that a lamp must be specially constructed for burning either of these three fuels.

Before entering on a description of the manufacture of these lamps, it will be necessary to refer to an objection entertained by many eminent blowpipe analysts of my acquaintance—more especially by those who have been students at Freiberg University—to the pyrological use of coal-gas as fuel.

They say (what is quite true) that gas is invariably adulterated, more or less, with sulphur compounds; and, secondly, that as the travelling mineralogist or pyrological chemist cannot hope to obtain gas on the scene of most of his operations, it is a mere waste of time to teach him how to conduct these operations by means of gas as fuel; he ought therefore (they say) to use only oil or candle-lamps, in order that he may not be misled or betrayed by any sulphurous "reactions" [I shall explain all these hard words when I come to use them on my own account], or by the "fatal facility" obtained in operations with gas, in consequence of its comparative cleanness, absence of wick-trimming, greater heat, &c. Now, with regard to the first of these objections, the presence in some shape or other, more or less, of sulphur compounds in gas, although that defect certainly is invariable, it has not seemed to me, after an experience of some 12 years, to produce any great difference of results from those realised by a previous 12 years' experience in operations conducted exclusively by means of oil and candle-lamps, except, of course, in cases of testing *for* sulphur and its compounds, when the latter alone must be used.

The second *dictum* of restricting the operator at home to the use of oil and candle-lamps, because they are inferior to but more easily carried or procured than gas, is, it seems to me, about as reasonable as to require a chemist to use only in his home laboratory the little dropping-bottles of nitric or hydrochloric acid which he is compelled, for reasons of portability and convenience, to use on his travels in testing limestone rocks, &c., for carbonic-acid gas.

I would, therefore, strongly recommend my student not only to use a gas-lamp, but the most powerful of all pyrological lamps, a hot-gas lamp worked by a foot-blower, as soon and as long as he can procure it, and when he can no longer do so, to tax to the utmost his ingenuity, in order to increase the power of his oil or candle-lamp so as to use constantly a foot or hand-blower with it also. I believe a good deal could be done with a petroleum-lamp, but having never tried one, I shall, as Berzelius says, "pass it by" here.

Of oil pyrological lamps, by far the best, and, indeed, the only one now known, is that invented by Berzelius himself* (Fig. 13), which he filled with common olive or even rape-seed oil; but when pure cocoa-nut palm oil, as it is sent from Ceylon, can be procured for this lamp, it is simply perfection in the way of oil-lamps, as this oil becomes solid at a temperature of under 70° F., which renders it extremely portable, whilst it affords a perfect "pyrocone." The following account, condensed

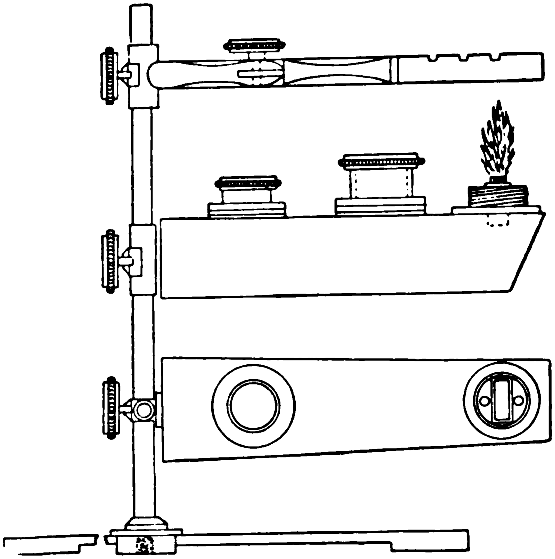

Fig. 13.—Berzelius's Oil Lamp.

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[*] There are strong reasons for believing that this lamp was the invention, not of Berzelius, but of his teacher, Assessor Gahn, of Fahlun.

from Dr. Scheerer's "Introduction to the Use of the Blowpipe," translated by the Editors of the London "Annals of Pharmacy and Practical Chemistry," published by Freeman, 69, Fleet Street, 1853, describes

The way to make a Pyrological Oil-Lamp.

First, make the chamber K (Fig. 14, which is about one-third the natural size) of tinned iron or brass, by bending round the bottom, and employing as few

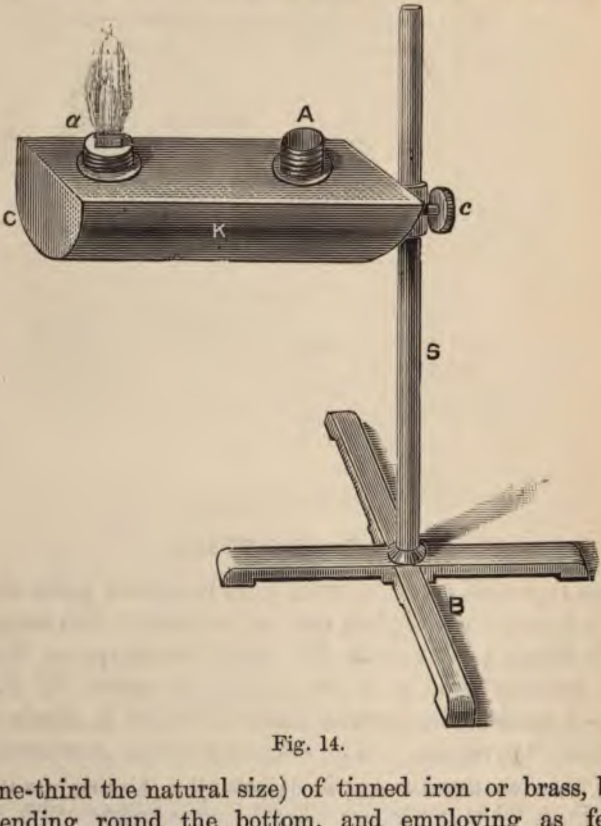


Fig. 14.

solderings as possible. "This may be lacquered externally black or brown, and should be attached to a metal loop with clamping-screw *c*, to move up and down upon the perpendicular rod S. Oil is poured in at the opening A, which is closed by means of a screw-cap B, Fig. 15; *a*, Fig. 14, and *a′*, Fig. 15, is the socket for the wick (made of strands of plaited cotton), which should be covered, when not in use, by a screw-cap similar to B. The principal construction of the socket and the opening for the wick may be perceived in the outline *a′*, and from the anterior view *c′*, Fig. 15, also in the larger drawing at C. The lamp-chamber K should be screwed securely at an elevation equal to that at which the blowpipe is to be held, and a convenient place obtained on the table to support the arm which holds the blowpipe." I may add to this account, that the stand is made of two cross pieces of brass B, screwed together by the perpendicular rod S. I now proceed to show

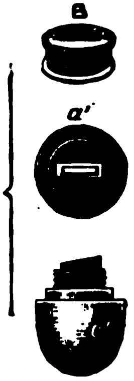


Fig. 15.

How to make a Pyrological Candle-Lamp.

Make of any good conducting metal, as zinc, a strong oblong box, about the size of A *a* (Fig. 16, section), one end being partly closed by a rectangular four-sided plate, the narrow sides of which taper inwards like the frame of a slate, as shown (in plan) at B, Fig. 17. Into the box is slipped a rectangular candle of the same shape, having the double wick running near and parallel with, but not quite along, one of its two short sides, A *b*, Figs. 16 and 17. Even if I could myself make candles, it would scarcely be expected that I should have space or time here to give a description of the manufacture, but I may mention that the largest candle-makers in the world—Messrs. Price & Co., of Battersea—have a special mould for "pyrological candles," producing individuals the size and shape given in Fig. 16; the late Mr. Hatcher, their manager, having been so good as to call on me in Woolwich in 1874, to obtain directions

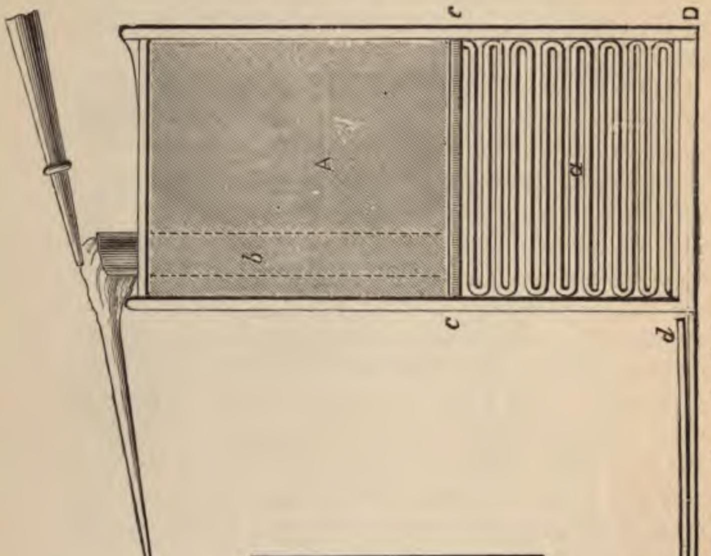


Fig. 16.—Ross's Candle-lamp.

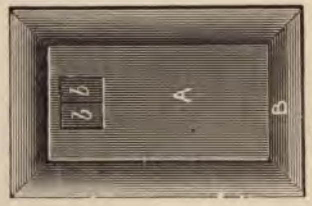


Fig. 17.

as to their manufacture. I have no doubt, from my knowledge of their liberality and public spirit, if my name is mentioned in any communication to that firm (which should ascertain from them the *exact* size of their candle), that they will retail such candles to *bonâ-fide* artisans at *wholesale prices*, especially if a number of workmen club together to purchase them. Fig. 16 represents a little more than half of one of their pyrological candles (for of course they can be cut into any required lengths) A *b*, resting on a metallic plate *c*, which again is supported and pressed upwards by a spiral

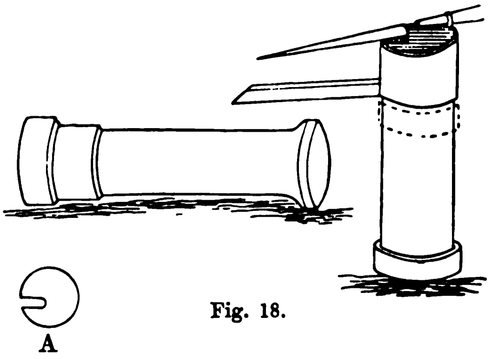


Fig. 18.

steel spring *a*. The candle and spring being placed or rather pressed in position, the bottom of the box is closed by sliding through slots or grooves cut in the inner bottom, longest sides, a long zinc or iron plate D D, the front part of which, D *d*, acts as a tray for catching fallen beads, &c.; and upon this tray the owner may also place his aluminium plate (to be afterwards described) when not in use, as it makes a far better tray than any other metal does. Figs. 18 and 19 are older and simpler forms of candle-lamps. A (Fig. 18) is a mould of spare "wax" for fitting into the round candle about the wick. In conclusion, as regards oil and candle pyrological lamps, it should be mentioned that as they are generally used with hand-blowers (see Chapter I.), the jet and nozzle of the blowpipe must be carried upon a stand capable of directing them up and down upon the flame at any required angle. The best and most portable stand I have yet seen is that devised by Fletcher, of Warrington; it consists of three joints with a stand-piece for the lamp, of flat thin brass, and can be folded so as to be carried in the waistcoat pocket (see Figs. 12, 23, and 14, p. 30, in my "Manual of Blowpipe Analysis"). The candle-lamp can be fed at top with melted fat, dripping, or even oil, so that one candle can be made to last almost indefinitely. A very excellent and practical fat or dripping pyrological lamp has been simultaneously devised by Dr. Foster, F.G.S. (who has given a description of it in the *Mineralogical Magazine*), and by Lombardi, of 4, Argyll-place, Regent-street. It can be easily made of the closed end of an old iron gaspipe about 2 in. diameter (price 2d.), which contains an arrangement of zinc foil for carrying the wick at any point of the inner circumference, and is filled with melted fat. The whole article, with fuel, ought not

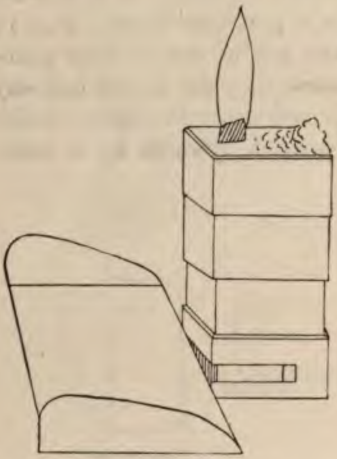


Fig. 19.

to cost more than 6d. The instrument for "snuffing" these lamps will be described under the head of "Apparatus."

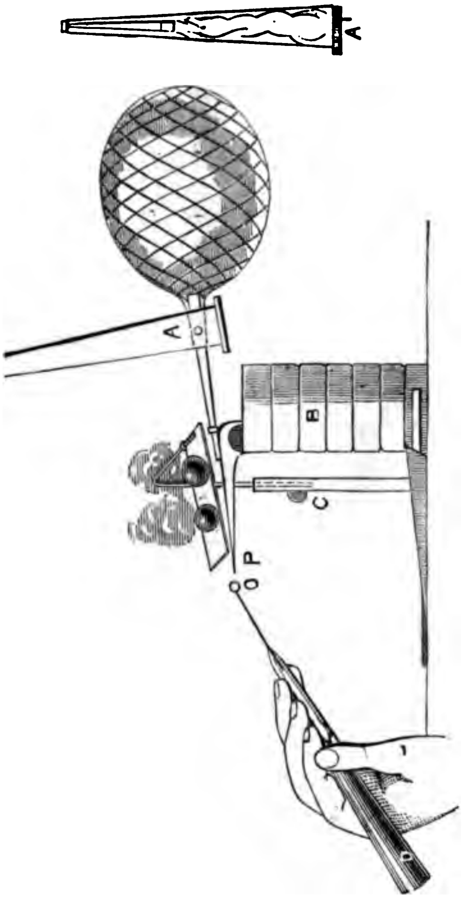


Fig. 20.—Ross's Blowpipe, Candle-lamp, and C. Griffin's brass-wire Boiling-stand.

Fig. 20 is an outline sketch of another form of air-reservoir blowpipe and candle-lamp, with tray, in use.

C is a stand made of brass wire, containing platinum or aluminium capsules, heating during operations, over the "pyrocone" or "flame"; D shows the mode of holding the object operated upon; A′ is the blowpipe packed for travelling.

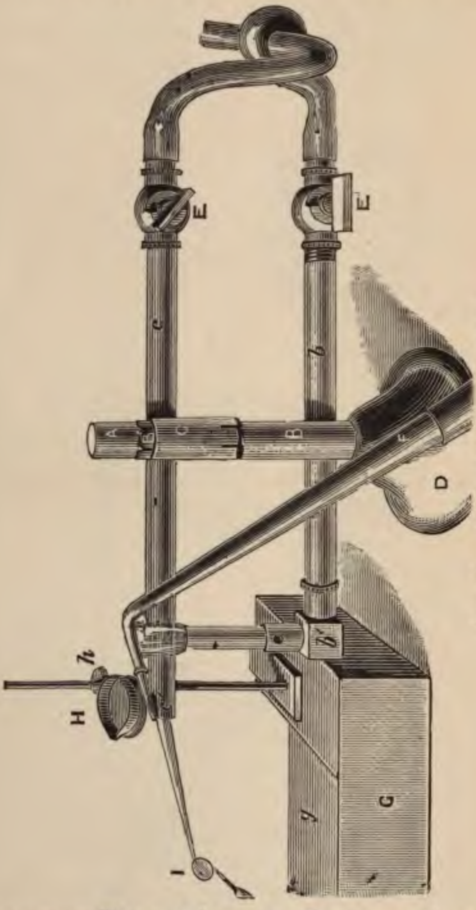


Fig. 21.—Lombardi's Hot-gas Lamp.

How to make a Pyrological Hot-Gas Lamp.

A (Fig. 21) is a brass tube, or, if preferred, a rod about the diameter of the "body-tube" of the blowpipe (Chapter I.), which screws perpendicularly into a heavy metallic (lead or zinc) pedestal D, which should have a small projecting lip or point: if the ledge of the hot Al plate is placed under this point, the plate will stand upright. Upon this brass tube fasten loosely by flanges at B′, so that it can slide up and down, but remain fixed at any point, the tubo BB′, to which is soldered near its lower part at B the horizontal tube *b*, carrying a short Bunsen burner *b′*. Now slip over the top of tube B B′ another, similarly flanged, but much shorter tube C, with its flanges pointing downwards, carrying, by means of a solder near its top, the tube *c c′*, which has a small slot or elliptical hole cut in its upper end *c′* for the insertion of the foot-blower nozzle. These tubes (*b* and *c*) communicate by means of the gas taps E′ and E respectively, and two elastic tubes (connected with one main elastic tube by the triangular pipe, Fig. 22) with the house gaspipe at any gas-bracket. F is an ordinary goldsmith's blowpipe connected by an elastic tube with a foot-blower under the table (Chapter I.). G is a box which can contain any small apparatus, covered by an aluminium tray *g*, for falling beads, &c.; H, a pla-

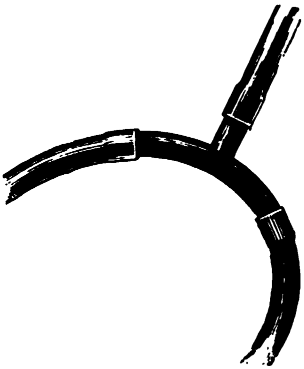


Fig. 22.

tinum dish clamped on an iron pillar *h*, over the base of the pyrocone, containing boiling distilled water for

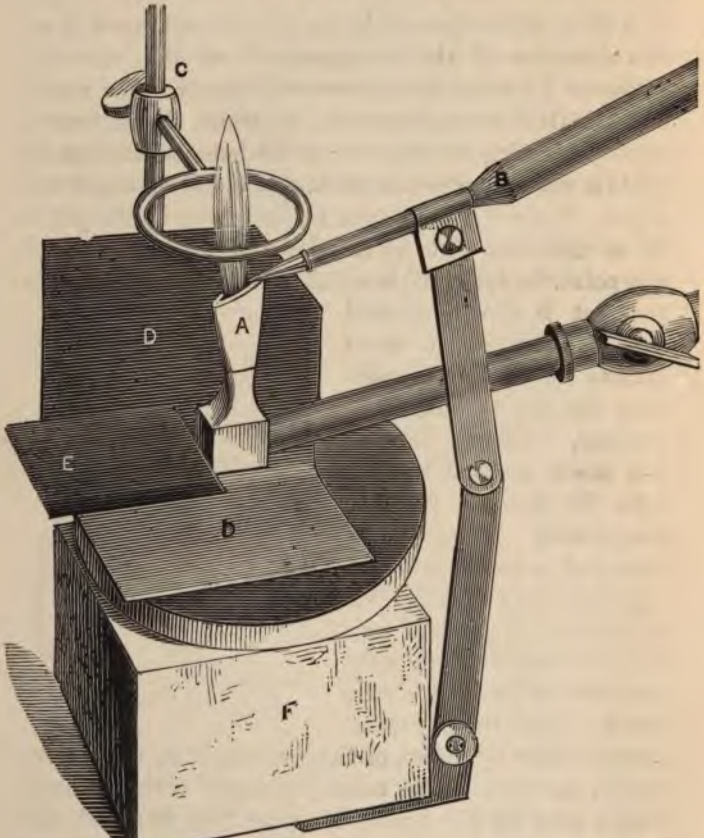


Fig. 23.—Cold-Gas Lamp with Fletcher's Jet-carrier.

dissolving boric-acid beads, and obtaining the insoluble borates formed within them by the action of the blowpipe, as will be explained in a future lesson on

"Reagents." The tubes *b* and *c* can evidently be used separately, if required.

The above-described apparatus forms the most powerful and useful chemical blowpipe known, excluding, of course, the oxyhydrogen, and such blowpipes as Herapath's, of Bristol, in which the blast is directed from the centre of the gaspipe. All such, as well as the pyrological use of an ordinary Bunsen burner, paralyse and jumble together the chemical effects of oxidation and reduction, for which the ordinary blowpipe pyrocone is so justly celebrated, and cannot, therefore, be used here.

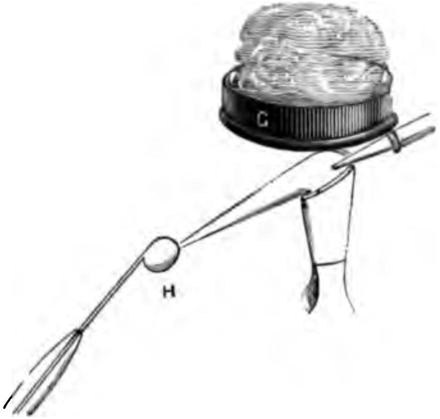


Fig. 24.

The sketch accompanying this description is taken from an instrument designed and made for me by its inventor, my old pupil, M. Lombardi, who showed me by a series of experiments which place the matter beyond doubt, that heating the gas is far more effective in obtaining this result than heating the blast, although it must be observed that Mr. Fletcher's "hot-blast" apparatus heats the gas as well. The whole thing, excluding the platinum dish, ought not to cost more than a few shillings.

Fig. 23 is a rough sketch of an extemporised single gas-lamp, worked with a hand-blower. B is the blast-pipe carried on one of Fletcher's portable stands; C the brass ring for platinum capsules; D D a blackened zinc plate to act as a background against the blue "flame;" E an aluminium tray; and F a small box on which the gas-burner rests. Fig. 24 shows the capsule with water boiling over the pyrocone, while the bead or "assay" H is under treatment.

CHAPTER III.

ON SUPPORTS AND APPARATUS.

Before setting about his work, the student of pyrological analysis has to make, adapt, or acquire several instruments, subordinate, indeed, to the two chief articles, a blowpipe and a lamp, the manufacture of which has formed the subject of the first two chapters, but still absolutely necessary, and indispensable to all progress. It will be evident to him on reflection, that having produced, as above described, what has been generally miscalled the blowpipe "flame,"—for it is in reality a beautiful cone of solid, dark-blue fire with an extremely acute "vertex," ending in a point as fine as that of a needle, and which should, therefore, be called not a "flame," but a *pyrocone* (Greek *pur*, latinised into *pyr*, fire, and *konos*), or cone of fire—he cannot hold in it the object on which he proposes to work, or the "assay," directly with his fingers, but must interpose between those delicate members and the fire some intermediate article or instrument which shall possess the twofold negative property of not being destroyed by such intense heat, and of not being even acted upon by it so as to communicate any part of itself, altered as by "oxidation" (which term I shall explain in another part of these lessons) to the above-mentioned "assay."

mentioned aluminium-plate, first used by Colonel Ross, and described by him in his book, 'Pyrology.' Having worked for some time with this, and, after long and careful trials and comparisons with charcoal, I have found it so very excellent and useful, that I think some remarks upon it may be of service to those who have not yet tried it. . . . It is, certainly, a pity that anybody should continue to use charcoal when there is something so much superior to be had. . . . The plate is not only a great gain as to the portability, cleanliness, *and expense,* but also gives, in most cases, much better indications of the volatile substances sought for." Again, "Berzelius laments the difficulty of procuring good charcoal when travelling, even in the well-wooded regions of the North, and this difficulty, and the consequent necessity of carrying about a quantity of dirty charcoal, all travelling analysts must find an annoyance." (Griffin's "Chemical Handicraft," p. 372.)

How to make the Aluminium-Plate Support.

Procure a rectangular strip of aluminium plate *not less* than four inches long by two broad, 1-32 inch thick, or of the thickness of this line ▬, half an inch of one end of which should be turned up by pressing it, while the metal is warm, firmly on a table, and bending up (*not too sharply*) the remaining portion in a vertical position, with both hands, to an angle of 95°; or a right-angle will do (Fig. 25, A C B). This half-inch horizontal part now forms a little ledge or rest for the assay, which, whether it be composed of one of the volatile metals, as bismuth, antimony, &c., (so ruinous if heated with platinum) or of mineral powder fused with soda or potash, before the blowpipe (C, Fig. 25), can be

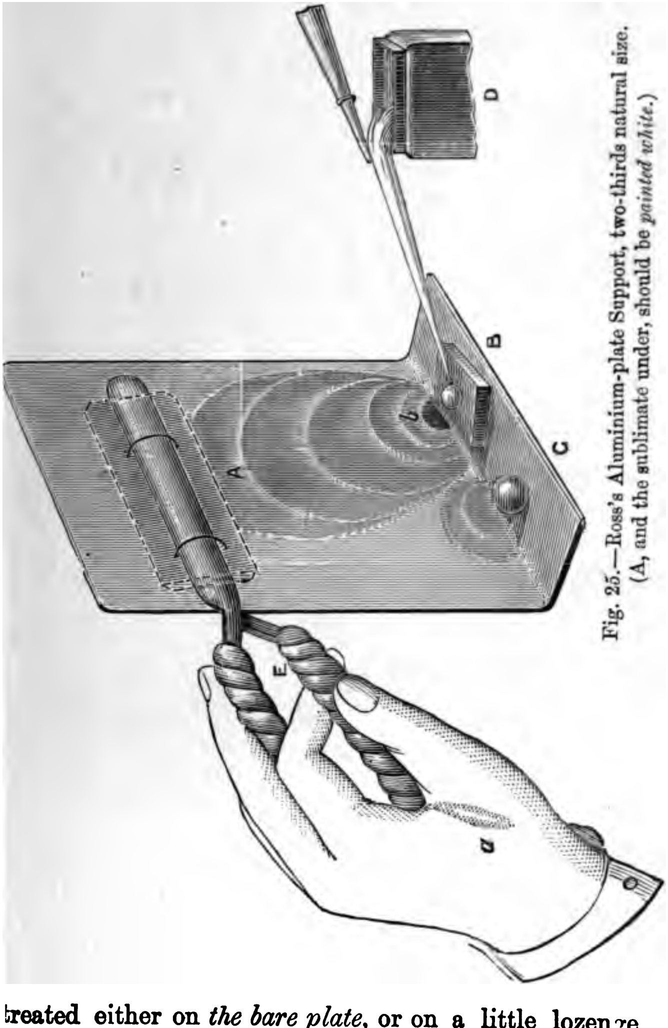


Fig. 25.—Ross's Aluminium-plate Support, two-thirds natural size. (A, and the sublimate under, should be *painted white*.)

treated either on *the bare plate,* or on a little lozenge or "slip" of charcoal B, the plate meanwhile being

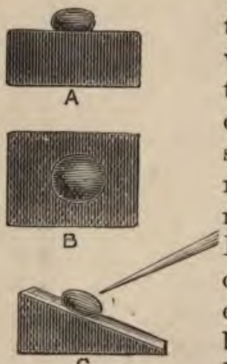


Fig. 26.

held by an ordinary iron pressure-opening forceps, having long flat blades, and muffled with list or flannel wrapped round the handle to protect the fingers, which would otherwise be severely burned by the tremendous heat-conducting powers of this metal, E, Fig. 25 (*a* in which shows the scar of a very severe burn received by me when first experimenting with aluminium plate in India). Fig. 27 gives a side view of these forceps. The corners and edges of the plate can be rounded by filing, to prevent tearing any lining of the blowpipe-case. These figures will again be referred to in describing the *use* of apparatus; but it may be mentioned here that the dotted lines near A, Fig. 25, represent a thin, flat rectangular slab of charcoal, fastened by two pieces of thin wire over the front leg of the holding forceps for the purpose of recording the charcoal reactions of sublimates, as it is a little addition of mine to this invention lately described in the *Chemical News*, and now figured for the first time. It is outlined in dotted lines because it will only be seldom employed, and to show the shape of the forceps-blade underneath.

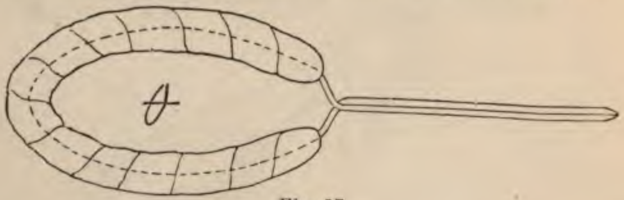


Fig. 27.

N.B.—Messrs. Johnson and Matthey, of Hatton Garden, sell aluminium by weight (and cheaply, considering its specific gravity is *extremely* low); and, I believe, allow half price by weight for old scraps as with platinum. The plate is cleaned by dipping a piece of rag (silk rag of old umbrella covers is best) wrapped round the forefinger, in charcoal dust and water, and rubbing well at the spots or stains. If the charcoal slips are sawed over a porcelain dish or basin (*d*, Fig. 64) containing water the necessary paste will be obtained. "The best way is to work as follows:—A fragment of the substance, about half the size of a small pea—or if it decrepitates, a corresponding amount of powder made to a paste with water—is laid upon the ledge of the base plate, close up to the angle (as C, Fig. 25), and heated very slightly, about half an inch from the tip of a pure blue flame which is directed downwards on the assay with a gentle blast. Any sublimate obtained should be examined from time to time: the heat being increased after each examination, till finally, very little or nothing more is obtained. The sublimates are then cleaned off, the same fragment of substance is placed on one of the slips of charcoal, in a small cavity in its centre (as B, Fig. 26), and again gradually heated, and the sublimate examined as before, till finally, in the strongest heat, nothing more is given off. The flame should always be so applied that its tip does not come nearer than half an inch to the assay, as long as any sublimate is obtained, and only in cases where nothing is given off, should it be brought so that the tip of the blue cone covers the assay. The reason for this is that some of the sublimates are so very susceptible of reducing action that if the flame were brought up too close they would be altered before they could be observed.

If no sublimate is obtained, either in the O F., or in the blue tip, the powdered substance should be mixed with its own bulk or rather more of sodium carbonate, and the paste heated on charcoal slip within the blue tip" (*Hutchings*).

Fig. 26 shows three charcoal "slips," the size and shape in which I use them; but of course they may be of any shape, or of no shape at all. A is the side view of a new one carrying a metallic assay. C *ditto*, of one partly burned away at the point of an oxidating pyrocone. B is the view from above of an empty new one, with a hole bored in it by a penknife for the assay. (The assays should be perfect spheres, and not oblate spheroids, as here shown.)

Fig. 28 is an outline sketch of an aluminium plate graduated to show the differing ascensive force of sublimates, with wadded tongs, resting on an ordinary 4-oz. stoppered bottle.

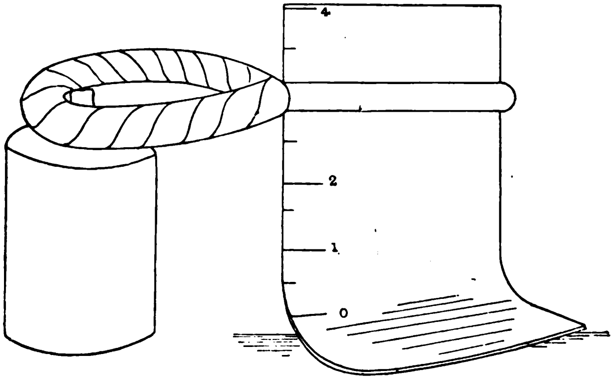


Fig. 28.

In case the student should be compelled or prefer to employ the old lumps of charcoal as a support, the following remarks regarding its use are extracted from the latest published work on the subject—Prof. Cornwall's "Manual of Blowpipe Analysis, &c.," New York, 1882, and exhibit some of the drawbacks alluded to:—"The charcoal must be well burned, compact, but not too hard, of light wood, bass wood, pine, alder, or willow, and must yield only a little greyish or white ash, since a coloured ash may lead to mistakes in qualitative work. It is cut into prisms about 90 millimetres long (1 in. = 25·399 millimetres; therefore 1 millimetre = 0·03937in.) and 25 square, so as to show on two opposite side faces the edges of the rings of annual growth, which should be rather close together, and the substances treated are to be laid on one of these faces. When both faces have been used, they are cleaned with a knife or rasp (a very dirty operation, in which hands and face are covered, and lungs filled with charcoal dust), or the block may be sawn through lengthwise. Great care is necessary in using charcoal a second time, to see that no mistakes arise from the presence of some of the substances already treated. Bits of charcoal can be used, except when coats are to be obtained, being held by some proper support. Natural charcoal is by far the best for qualitative work. When it cannot be had, the artificial coal (made of rice or starch-paste, an invention of the late Mr. J. Griffin, of Garrick Street) may be shaped in suitable moulds readily devised."

Glass Tubes as a Support for the Assay *per se.*

The "open-tube" A (Fig. 30) and "closed-tube" B (Fig. 29) may be classed here, although they are, especially B, rather used over the flame of a spirit lamp, or the Bunsen (Fig. 21, *b*',) than as "supports" for assays before the blowpipe. A is made by heating any point of a piece of hard, white, German-glass tubing, the diameter of the figure (price 1s. per lb.) in a spirit-lamp flame, or *gradually* (or else it will break) before a blowpipe, to redness, and then, holding the tubing with both hands, one on each side of the red-hot point, gently bending it to the angle shown in the figure, and cutting a tube the size and shape of A off the tubing by means of a small file moistened with a drop of turpentine. The "tube" B (natural size) closed at top by the tip of the first finger, is a miniature test tube, more easily and cheaply bought than made, except by a glass-blower; it is sold I believe (of the best German glass) for a penny, and is a much more useful article than A, most of the results of using which are better obtained on aluminium plate, and, on the other hand, B may be used as a kind of open-tube by employing the holder, Fig. 31,

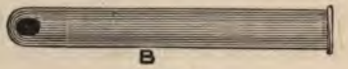


Fig. 29.

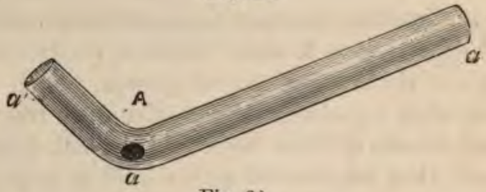


Fig. 30.

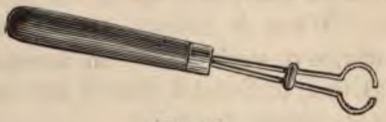


Fig. 31.

the manufacture of which will not, I am sure, present any difficulties to an English student.

The assay is often required to be supported *per se*, more especially in testing minerals, &c., for the "coloured flame," or *pyrochrome* (Greek *pur*, fire, and *chroma*, colour) it may emit before the blowpipe, in a pair of *forceps with platinum points* made of brass or German silver, Fig. 32, the French pattern; which is the best, as the ends without platinum (*a*) are more capable of picking up small objects than in other kinds, as Fig. 33; the platinum tips (*á*, bought by weight as usual) are generally riveted on with small brass pins—a bad arrangement to my mind, as I find they invariably break off, after a year's use or so, at these rivet holes; a better plan, I think, but I have not tried it, would be to "strap" them firmly on with very fine platinum wire, which, when so thin, is cheap; because, I imagine, on account of the brass rivets passing *through* the platinum, which is so constantly and suddenly heated to redness and even whiteness, that a kind of pyro-electric action is "set up" between the two metals, and that this weakens the platinum and strengthens the brass. Thick platinum wire, bent round the assay, as shown

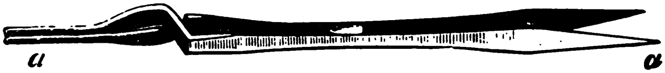


Fig. 32.

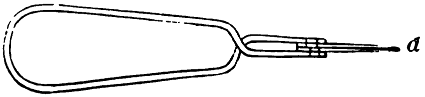
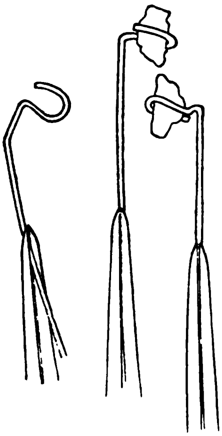


Fig. 33.



Figs. 34, 35, 36.

in Figs. 34, 35, 36, may be also used as a *per se* support.

Platinum Foil is very seldom used now, as a *per se* support, but Prof. Cornwall says: "It should not be too thick, weighing about 110 to 120 milligrammes (1 mgr. equals ·154 gr.) per square centimetre (1 in. equals 2·5 cent.), cut into pieces 40 millimetres (about 1·5 in.) long by 25 wide, and it may be held by forcing its edge into a piece of charcoal. *Note.*—Never heat a metal, metallic sulphide, or arsenide, in contact with platinum."—(Page 14., "Man. Bl. Anal.")

Supports for Fluxes or Beads—The Platinum-wire Support.

This invention (by Assessor Gahn, of Fahlun, Sweden) is one of the most beautiful, perfect, and important, that was ever contributed to Blowpipe Analysis. The thickness of wire depends upon the size of bead required by the operator, and this again (within the limits of the law of gravitation), upon the "energy" of the pyrocone employed; for it must be evident that an ordinary mouth-blowpipe, though used by ever so good a "hand," will fail to produce by the heat of an oil lamp such a large bead, especially of boric acid, as the instrument shown in Fig. 21 could. After long practice and reflection on the matter, I have come to the conclusion that the largest possible bead, and therefore the thickest possible platinum wire, is best: but instead of troubling my students with "millimetres" or other French metrical expressions resolved into English inches, I have thought it the best plan to give exact pictures as to thickness, shape, and length of platinum wire-supports, Fig. 37, in which *a* represents the wire I use; *b* (Fig. 38) that generally employed; and *c* (Fig. 39) that (incredible as it may seem) figured as the proper thing in some modern English works on chemistry.

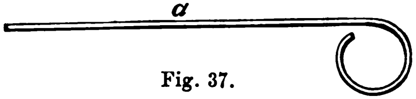


Fig. 37.

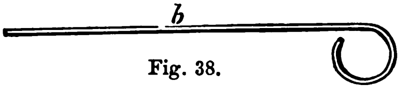


Fig. 38.

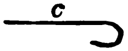


Fig. 39.

At Freiberg I purchased, in 1867, a beautiful mahogany case of blowpipe apparatus for 133 thalers (£20), containing, among other exquisitely-finished but superfluous articles, a little boxwood and German silver handle for holding these platinum-wire supports—"Only this, and nothing more." But in a case where compactness and portability of apparatus are among the chief claims to the attention of scientific men put forward, as in Blowpipe Analysis, it is absolutely necessary to devise subordinate articles which shall answer at least two useful purposes, and I have therefore proposed as a holder, cleaner, straightener, and ring-maker of platinum wire, an instrument which also serves as a really powerful magnet, and a magnet is a *sine quâ non* (Latin, "without which, not") of a mineralogist's blowpipe apparatus. This instrument

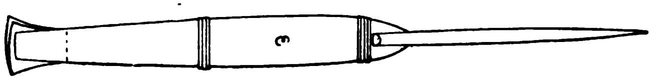


Fig. 40.

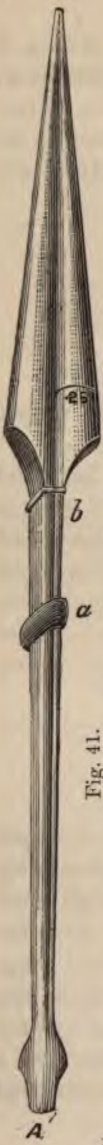


Fig. 41.

is a modified jeweller's pliers (Fig. 40), but made of steel and burnished. Fig. 41 shows it with the legs closed, and Fig. 42 with them open. Both are of the natural size, and exhibit a semicircle at nearly the bottom of the right leg, which may, or may not (according to the maker's ability), have ·25 stamped near, as this is the place where a ring ·25 (or quarter) of an inch in diameter may be made upon the platinum wire; which is the size of bead generally made by me. The large round legs, apparently perhaps too large, but not so when practically tested, enable the operator, by holding the very tip of a straight platinum wire firmly between them from below, at the part marked ·25, and gently turning the pliers round with his right hand towards his left, which holds the wire, to make a good round ring like that of *a*, Fig. 37. The ordinary "cage-maker's pliers" (Fig. 43) also serve this purpose

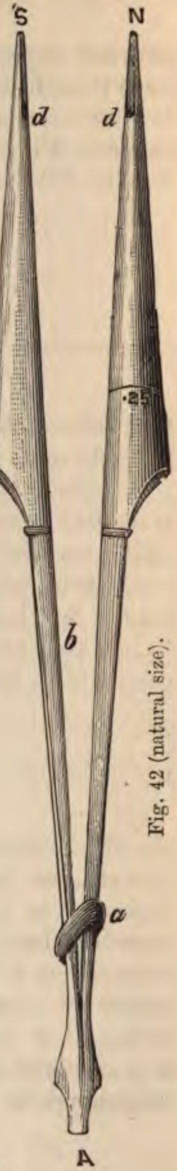


Fig. 42 (natural size).

Figs. 41, 42, Ross's Magnetic Pliers.

excellently. They may be graduated, as shown in the figure. The wire is straightened and cleaned by squeezing and drawing it gently through the broad flat inside part of the legs at *b*; and this process is much more effectual than that generally recommended by chemists, to dip the red-hot wire in hydrochloric acid, which also most certainly renders the wire brittle and causes it to break in "ringing" after a time, whereas this process strengthens it by a kind of welding. The ringed wire is now fixed between the legs as far as *d*, Fig. 42 (not farther), in the shallow space cut out for it, by drawing up the brass collar *a* Fig. 41, to the position shown; by drawing it down to *a*, Fig. 42,

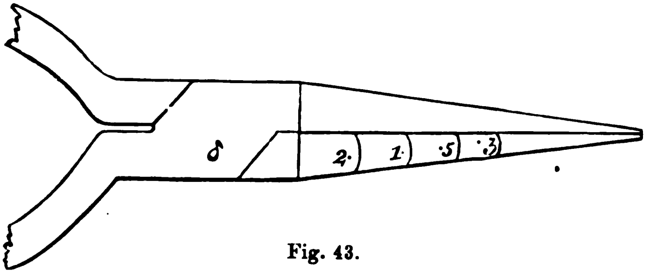


Fig. 43.

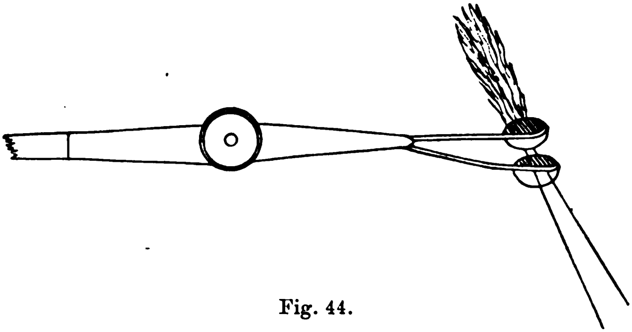


Fig. 44.

the legs are left wide open, and the pliers are then useful in the ordinary way, for taking up small articles or assays, &c. They are now to be utilised as a horseshoe-magnet in the following manner :—Left wide open

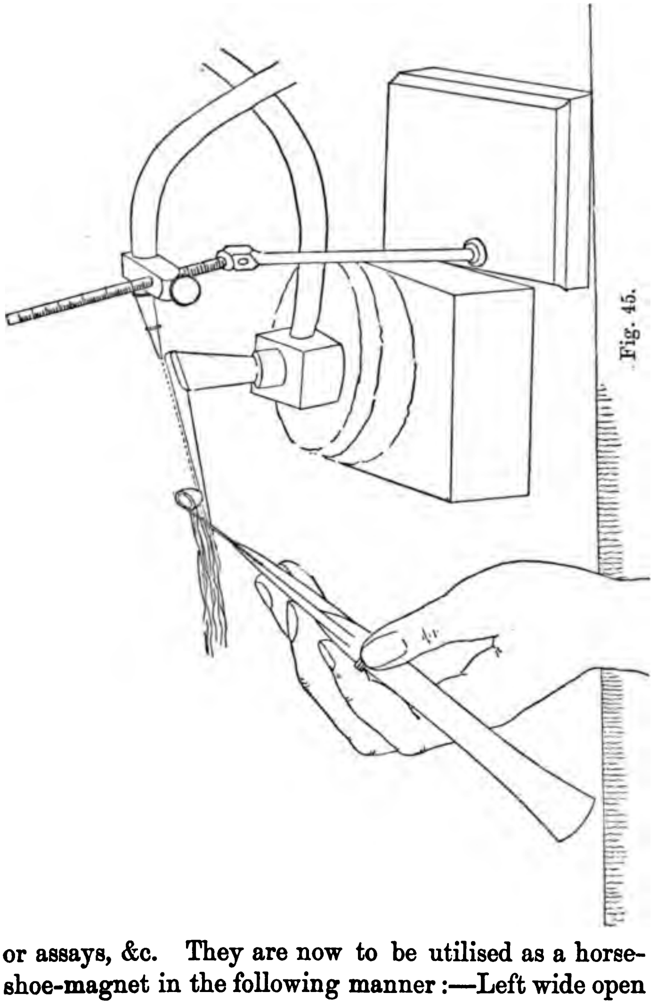


Fig. 45.

and laid flat—not sideways as shown in the Figs., the pole of a big horseshoe-magnet (the use of which would, I feel sure, be allowed by any shopman possessing magnets) marked "N" is to be carefully and squarely drawn down the flat side of the leg S, Fig. 42, from A to S; this is to be repeated, say, twelve times. The pliers are then to be turned over so that the other side is uppermost, and it is to be in like manner gently but firmly rubbed by the magnet, always in the direction from A to N, by the other, or S-pole of the big horseshoe. An armature is supplied by simply closing the pliers. The end A acts as a charcoal-borer or small screwdriver by putting a cork over the sharp points. A "geometrical pen" (Fig. 44) makes a cheap and capital support for beads on platinum wire, &c.

Mr. Letcher, of Truro, Cornwall, has devised a most ingenious telescopic stand holder for platinum wire, &c., and for Al plate on a pinch, though the grasp of the geometrical pen is scarcely long enough for that; but I have doubled this length by boring another hole for the screw nearly at the base of the pen "arm."

Fig. 45 is a rough outline sketch of an extemporised gas pyrological apparatus, showing the mode of treating the bottom only, of a bead containing the assay powder in the pyrocone or flame. This is essential in the case of unknown substances containing arsenic acid, &c. (see Tables VI. 3, col. 4, and VII. 3); otherwise, the platinum wire will immediately fuse, and the ring break off. When the presence of a volatile metal is certified, the bead is unrolled from the wire and the assay transferred to the aluminium plate.

CHAPTER IV.

ON AUXILIARY APPARATUS.

FREIBERG APPARATUS, in the profuse manner by which every one of the too-numerous articles is designed exclusively for its own separate use however trifling, and for no other, forming at last a bulky box which with its deal case is almost a porter's load in itself, actually contains two articles for merely cutting and trimming a lampwick; (1) a pair of common scissors, and (2) a "steel forceps;" but it is evident that these may be usefully combined as in Figs. 46, 47, and 48, by making or adapting a pair of ordinary small-size scissors, each leg of which terminates in a broad flat point (which can be used as a charcoal borer), *a*, Figs. 47 and 48. The wick is compressed, as it often requires to be, between these flat points at *a*, and cut in the ordinary scissors-part at *b*, Fig. 46. This instrument has been made by Griffin and Co., and answers very well; it is called *scissor-forceps*. I purchased, the other day, for 2s. 6d., a pair of ordinary grape-scissors (Fig. 49), the upper surface of which, *a*, answers capitally for compressing the wick, and the opposite or under surface for cutting it.

In like manner, the heavy steel hammer, with steel anvil and special steel forceps, all three for simply crushing small fragments of minerals to powder, and flattening malleable assays, contained in the Freiberg set and the English copies of it, may be usefully and even perfectly superseded by *one* little, extremely common, and very cheap instrument, known as "*dentist's* or *crushing forceps*" (price 1s. 6d.), the head of which is shown in Figs. 50 and 51. This, of course, may be of different shape (as, for instance, with square,

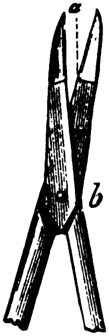


Fig. 46.

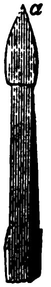


Fig. 47.

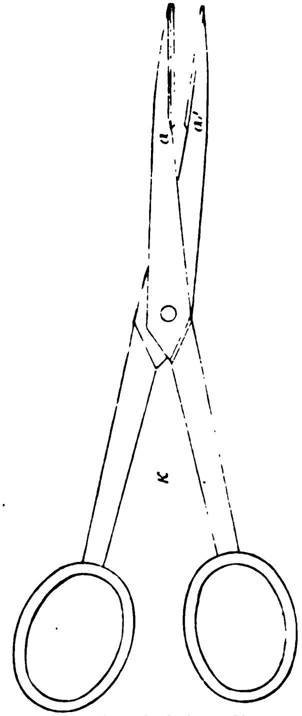


Fig. 48.—Ross's Scissor-Forceps.

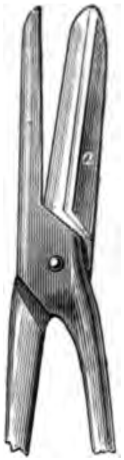


Fig. 49.

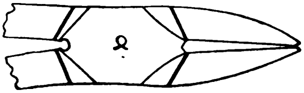


Fig. 50.

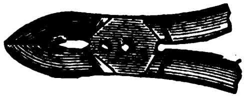


Fig. 51.

instead of rounded jaws) from that given in the figures, and yet be equally good; the only essential point is that there shall be an opening at *a*, without which there is less leverage, and consequently much less power. Figs. 52 and 53 represent the head of another useful and common steel forceps, called nippers, for nipping off crystals, or other desirable portions of a mineral upon which to operate. It may, but need not, have a little steel spring between the legs of the handle, as at *a*, in order to keep the knife-like jaws apart. If the artisan-student has a talent for invention, he may devise a combination of the two forceps (Figs. 51 and 53) in one, as Fig. 54, which is a modification of one of the champagne-cork extractors in use, with the nipping and cutting part, *a*, very much exaggerated, or *prononcé*, the French would say, and the screw-bottom, *b*, sufficiently large and protruded to enable it to act as a light but effectual hammer, although a hammer is really not required in blowpipe apparatus. This instrument could be easily unscrewed,

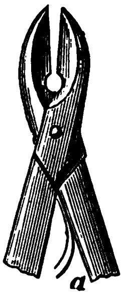


Fig. 52.

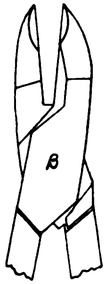


Fig. 53.

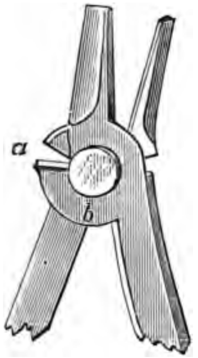


Fig. 54.

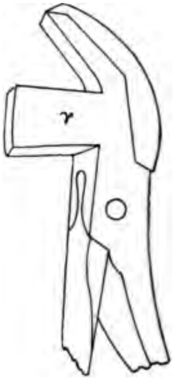


Fig. 55.

and the legs carried separately for convenient packing. Fig. 55 is a cobbler's implement, which may be used in the same way.

After crushing the assay-mineral roughly with the forceps (Fig. 50 or 54) instead of hammering it under a piece of paper (when, of course, you get the addition of paper fragments to your assay) or between the legs of steel forceps upon a steel anvil, as they do at Freiberg, it is necessary to reduce the coarse powder thus produced to fine dust, or using a drop of water, to paste; and for this purpose by far the best thing is *a pair of polished agate slabs* (Fig. 56). In Freiberg they use for this purpose—and German dealers have supplied with it all the chemical laboratories in England, making thus a lucrative trade—an agate mortar and pestle, the disadvantages of which seem to me as follow: (1) They are far more difficult to make, and proportionately expensive; (2) After the hollow surface of the mortar becomes (as it very soon does) full of minute holes by grinding silicates and other hard minerals upon it, small portions of different assays lodge in these holes, and get mixed together, so that the operator is deceived by his assay—a very serious thing in assaying some of the rare minerals, of which only a very small quantity is obtainable—and it is impossible to re-polish such a hollow surface, except by the proper polishing machine; (3) If you happen to break such a mortar in the field you are "done for," because it is impossible to work with halves or fragments of it, and it cannot be used as a flat "slab"; (4) Such a mortar and pestle are *most*

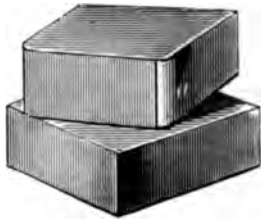


Fig. 56.

inconvenient to pack, except in the luxurious mahogany Freiberg case, in which spaces the exact shapes of them are cut out and lined with velvet (!) The only counterbalancing advantage offered by the agate mortar to these *very* serious defects is that there is less chance of losing in a hollow surface than from a flat one, any part of a powdered assay; an "advantage" wholly thrown away in regard to qualitative analysis (Latin *qualitas*, a quality or property), which is all we have to consider here. On the other hand, agate slabs may be any shape or size you like or can obtain, provided they have each one polished, plane surface. As mentioned in the introduction, I made a pair of excellent slabs by simply cementing or gluing a couple of old agate brooches (price 2d. each), into two square blocks of wood. Fig. 56 is the sketch of a pair made for me by Griffin and Co., one of which has a rounded corner, at *a*, for using it as a kind of pestle, with very little assay powder. But *any* side of these rectangular slabs answers for grinding with; and when any surface gets corroded or "holy," it is only a matter of a few minutes and of sixpence expense to have it reground and polished. Besides these great advantages, agate slabs afford beautifully clean and smooth surfaces upon which to rest hot or wet assays or dry powder to be neatly taken up by a red-hot "bead."

In order to save the agates as much as possible, and to retain every particle of a small, hard assay, it is very convenient, but by no means necessary, to have *a closed steel mortar* (invented by a German chemist named Abich, and therefore called "Abich's Mortar," see Fig. 57), of which Figs. 58, 59, and 60 represent a modification devised by myself. The outer surfaces act as a little anvil, if required, and

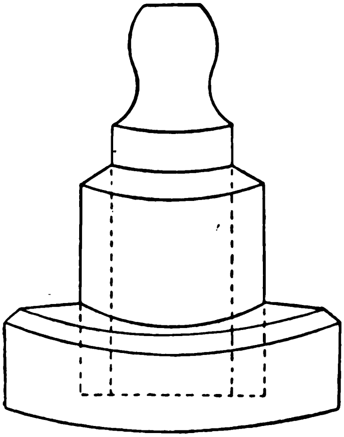


Fig. 57.—Abich's Mortar.

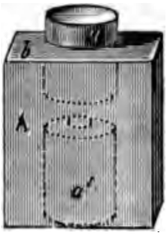


Fig. 58.

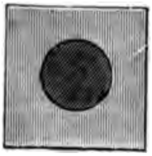


Fig. 59.

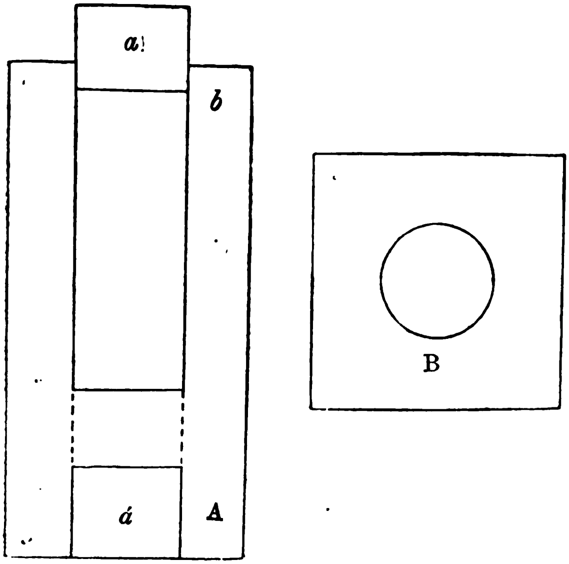


Fig. 60.

it is called, in consequence, *The Anvil-Mortar*. A *b* is a solid, hard-iron or steel square prism, of any size convenient to the owner. *a á* is a polished steel piston, or cylinder, passing air-tight into, and through a circular hole or chamber, with polished sides, which is very correctly bored through the long axis (Latin *axis*, an axle) of the prism. Figs. 58 and 60 A are a side view, and Figs. 59 and 60 B a top view, of the machine. The piston being divided into sections, the upper part, *a*, is withdrawn, and the mineral fragment or assay to be crushed dropped into the cylinder, upon the lower part *á*. *a* is now replaced over *á* carrying the assay, and gently tapped with a light hammer on its upper surface until that is level with the upper surface of the prism A *b*, which shows that the mineral is completely crushed. *Corundum* (the hardest mineral in the world next to *diamond*) can be instantly crushed thus to fine powder on a Brussels carpet, and the powder then obtained by pushing the piston through, upon a clean sheet of paper. In Abich's mortar, which has a closed bottom, the powder must be scraped or swept out. *A lens* (Latin, *lens*, a lentil-bean) or magnifying-glass, Figs. 61 and 62, is

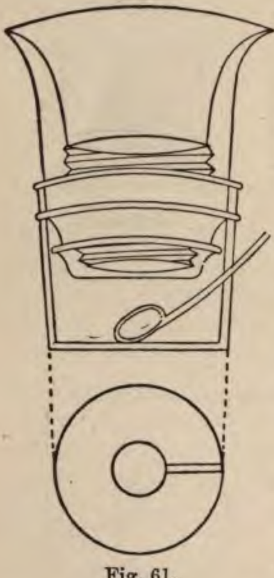


Fig. 61.

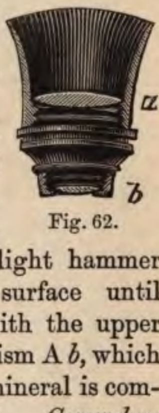


Fig. 62.

an indispensable accessory to a blowpipe, without which you could not properly observe the reactions which have taken place in the transparent, or semi-transparent, "bead." The figures show the ordinary watchmaker's shape, or "loup" (which is by far the best), cut in horn, but containing two doubly-convex (Latin, *convexus*, swelling or rounded, as the upper surface of an arch) lenses, which are pieces of glass shaped like a lentil-bean. The prices of good lenses are less than they formerly were, but they are still, in my humble opinion, far too much. With our numerous and splendid glassworks, the English artisan ought certainly to be able to buy a lentil-shaped, cut and polished piece of "crown" or "flint" glass this size for 6d. at the most: he can easily use this on a pinch without any frame at all, but a turner ought to produce such a frame as Fig. 62 out of a piece of horn for, say, 6d. more. At all events, the Americans are now selling in London excellent little lenses in German-silver frames, screwing into a plate with white bone handle, containing also a needle with piece of glass for holding the "object" (which is quite useless), all for one shilling! I purchased two of these the other day at an American shop in the Strand, threw away the handle and plate of one and the needles and glasses for objects of both, and screwed together the two lenses so as to form the small

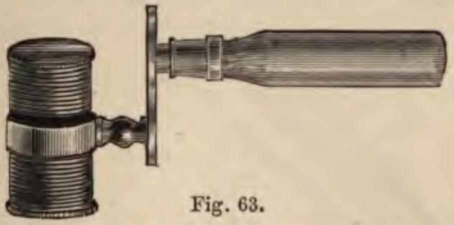


Fig. 63.

double-lensed hand-microscope, Fig. 63 (one-half the natural size), which has cost me 2s., and is a really efficient little thing: French lenses of large aperture, with "botanic stool," are now sold in the Strand for 2s. *A charcoal saw*, made by filing teeth in a broad 4 in. piece of clock-spring, after allowing it to cool from red-heat. The ends may be rounded to form a spatula. *Pressure-opening tongs* for holding and taking up Berlin porcelain or platinum basins containing boiling water (Fig. 64, *d*). These are made of a single piece of ordinary stout

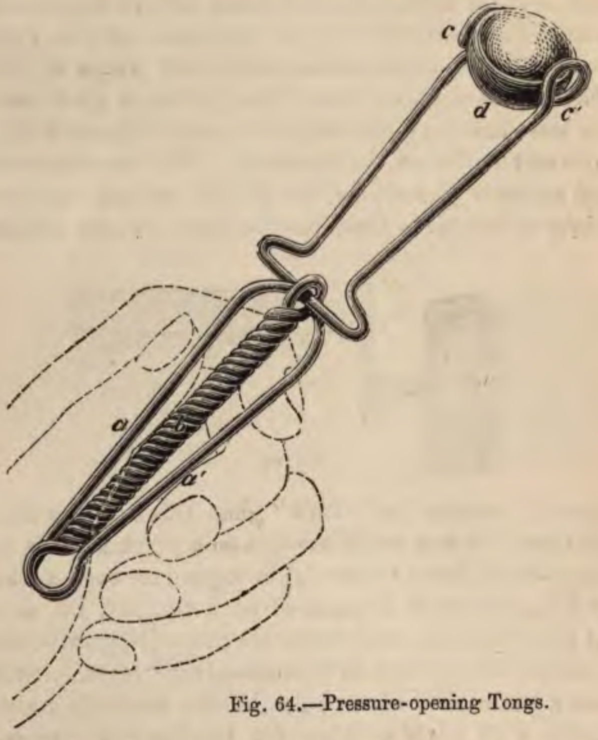


Fig. 64.—Pressure-opening Tongs.

iron wire, twisted in the manner shown in the figure, the elasticity of the outer sides of the handle of which, *a a'*, forms a strong spring, which exerts a pressure in the ringed legs *c c'* towards each other, and thus keeps the tongs always closed until pressure is applied to the sides *a a'*, when the legs immediately open; it is thus evident that the legs will hold anything (as a capsule or basin *d*, or even aluminium plate) very tightly between their rings *c c'*, and that, when the tongs are held in the fingers as shown by the dotted lines so that no pressure is applied to *a a'*, a little dish of boiling water thus clutched may be safely and easily taken from or placed over a spirit-lamp or Bunsen-burner, the dish being set free in its required position by pressing *a a'* towards the inner handle *b*. For simplicity, cheapness, and cleverness of construction these tongs are, in my opinion, unparalleled. I cannot ascertain the inventor's name, which I trust is English; but it ought certainly to be known and recorded. I bought several pairs at a shop near Argyll-place, Regent Street, for 4d. each. *A penknife* and *flat file* are often necessary: they require no description. *A magnetic needle*, made by magnetizing a lady's large hair-pin as described in Chapter III., and swinging it on a silk thread. A steel (or platinum) spatula is sometimes useful.

Glass Apparatus.

The Cobalt-solution dropping-bottle, Fig. 65; but the best shape consists of a little pipette with bulb-handle or top, passed through a cork up to the bulb into any ordinary small bottle (Fig. 66). Chemists sell them, I believe, made of German glass, for a shilling each. The heat of the hand expands and drives out a portion of the air in the bulb, and when the pipette is then (while the bulb is warm) placed in the solution, a portion is drawn into the pipette by "capillary attraction," and into the bulb with the returning air, and is expelled, drop by drop, when the bulb is again warmed by the hand. The figure shows a drop in the act of falling into the bottle.

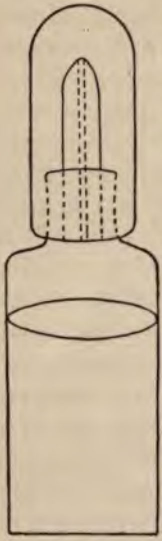


Fig. 65.

Fig. 67, *A Spirit-lamp.*—This is the best form, made in Germany, and sold by London chemists for a shilling each. (I am in hopes that when a million of my artisan-countrymen take to Blowpipe analysis, all these apparatus will be manufactured *in England* still more cheaply, and a great trade thereby obtained.) *a* is a brownish, unglazed porcelain wick-holder, shown half the natural size in Fig. 68, which fits loosely into, and just below, the neck

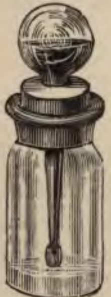


Fig. 66.

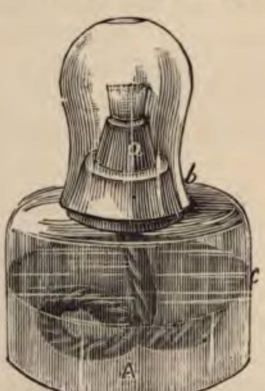


Fig. 67.

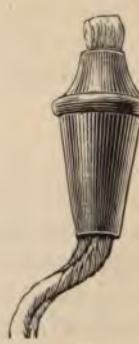


Fig. 68.

of the blown-glass bottle A; this latter is slightly ground outside, so as to fit closely against the ground inner bottom of the glass cap *b*; the tail of the plaited cotton wick (which should be pretty long, to suck up as much "spirit" as possible), is left lying loosely at the bottom of the lamp, which should not be filled with methylated alcohol above *c*.

A dropping and washing-bottle, containing distilled water, Figs. 69 and 70, of exclusively German manufacture now, though invented, I believe, by an Englishman — Dr. Wollaston — is an indispensable accessory to the pyrologist who wishes to work in

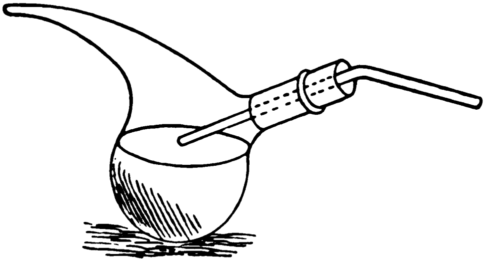


Fig. 69.

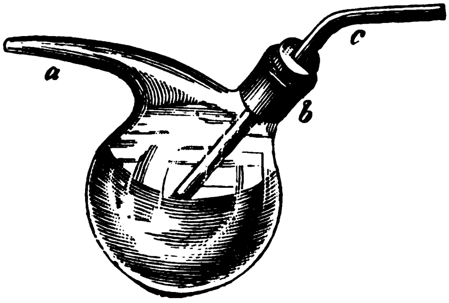


Fig. 70.

a cleanly and correct manner. It consists, as will be evident from the figure, of a small globe of blown-glass, drawn out at one upper side into a pointed beak or pipette, *a*, Fig. 70, which has a neck carrying a cork and small bent-glass tube, *b c*, at its base. When required for dropping, the bottle is taken up between the thumb (underneath) and two first fingers (on either side of the neck), and held with the beak downwards, when, after a shake or two, the water will flow in drops only, occasioned by the partial admission of air through the narrow tube to take its place in the bottle. When required for "washing" a small object, the bottle is held over it, beak down, and

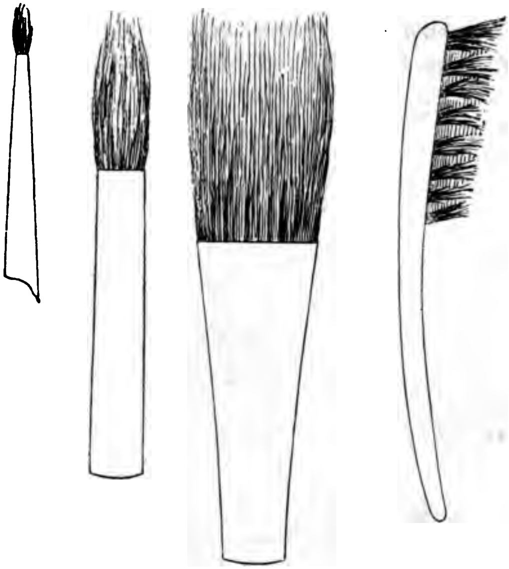


Fig. 71. **Fig. 72.** **Fig. 73.** **Fig. 74.**

Useful brushes of different kinds.

the tube gently blown through by the mouth, when a minute stream of water will issue from the beak; a *large* "subject" is washed by reversing the bottle and blowing through the beak, when a comparatively large stream of water will issue from the tube. A very good "dropping-bottle" for cobalt solution or pure water may be extemporised (Latin *ex*, for; and *tempus*, *temporis*, time) by corking an ordinary wide-mouthed bottle containing the fluid to be dropped with a cork having a glass tube passed through it into the solution. "If the tube is closed above with the finger, and withdrawn together with the cork, part of the solution will remain in the tube, escaping by drops when the finger is withdrawn" (Cornwall, "Bl. Anal.," 1882, p. 19).

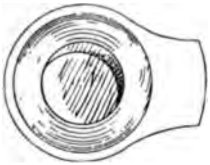


Fig. 75.

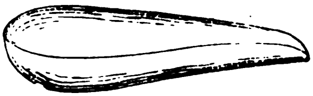


Fig. 76.

Fig. 75.—*Capsules* (natural size), of platinium or aluminium, with a flattened pistol-bullet for keeping it down when acting as a cover for Berlin basins containing boiling solutions: Fig. 76, a Freiberg horn or brass capsule for transferring powders or small particles to vessels with contracted mouths.

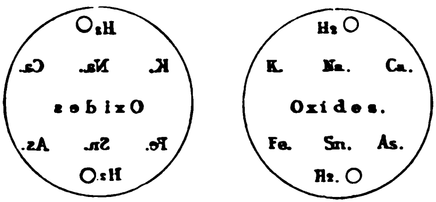


Fig. 77.

Fig. 77.—*Glass slabs* for keeping oxides, &c., on; these have chemical formulæ, &c., engraved *backwards* on one side, so that, when turned over, the letters are correctly exhibited through the glass.

CHAPTER V.

ON THE STRUCTURE AND MANAGEMENT OF PYROCONES.

THE student has now got his lamp, blower, supports, and auxiliary apparatus all ready; but before commencing operations it will be necessary to understand the nature and action of the fiery agent—" the genius of the lamp "—by means of which he is about to work, and to produce which he has taken all these pains. There is a great deal of truth in Griffin's remark (at p. 40 of that very excellent little book " On the Blowpipe," published in 1827, which immediately succeeded that of Berzelius, and preceded by eight years that of Plattner, but was, apparently, neglected by English chemists of the day. *because* it was English, and not written by a professional chemist) that the long "explanations" regarding flame-structure, or rather candle-flame structure, to be found in most blowpipe manuals, " are very tiresome and very useless," and that, " in our opinion, correct notions respecting flame (Children)—such at least as can be got at the present time—are not, to the operator with the blowpipe, worth the trouble of acquiring." In the transmutation or so-called " translation," by J. G. Children, F.R.S., of the French translation of " Berzelius," a note extending over several octavo pages of these "correct notions" is given the unfortunate reader, in which the curious conclusion is eventually arrived at, that "the form of the flame of a common candle for instance, is conical, because the *greatest heat* is in the *centre* of the *explosive mixture*" (pp. 23-27).

But, although a knowledge of the cause of structure of a candle-flame (still, by the way, an open question) is doubtless, as Griffin says, quite unessential to a knowledge of the proper use of the blowpipe, the same remark most certainly cannot be applied to a knowledge of the structure of the beautiful dark-blue cone of fire or pyrocone, instantly formed by the application of a proper blast to the side of this candle-flame; and, fortunately, a few simple experiments, which can be made by the poorest mechanic in his garret in a few minutes, will place the anatomical structure (Greek *anatomé*, dissection), of this pyrocone before us, as completely as a scalpel would display the structure of a lobster to Prof. Huxley. All the experimenter wants is a mouth-blower (Fig. 3), a common candle, a little spirit-lamp (Fig. 67), and a window (in daylight, but not sunshine). *Experiment* 1. Taking the lighted candle in his left hand, and the mouth-blower in his right, he holds the former steadily for a minute *on a level with his eyes*, in front of (looking through) the window; he will thus plainly observe the heated-air, &c., undulations, rising like a faint waving cloud, from the candle-flame (*a a'*, Fig. 78). Now, keeping the candle in the same position, he sends a blast with his mouth-blower, the nozzle of which is kept in the position *c*, horizontally through these heated-air undulations, about half an inch above the point of the candle-flame. If he possesses ordinarily good eyesight, he will now observe *the shape of the blast,* passing like a phantom needle (*b*) across these heated-air undulations: this line is evidently the space occupied by the minute but strong current of air from the blowpipe, in which the heat waves are checked (and the line thus rendered visible), although they display very considerable velocity considering the small source of heat from which they emanate. *Conclusion or Fact.* The blast from a blower has the form of a *right line,* the thickness of the diameter of the nozzle-bore. *Experiment* 2. The experimenter now advances the nozzle of his blowpipe carefully downwards, and towards the base of the right side of his candle-flame (still held on a level with his eyes), pointed just over the wick, as at *c,* Fig. 79, and projects a blast from his mouth. The blue pyrocone instantly produced from the candle, Fig. 79, is something like what he sees, the heat-undulations, now invisible, taking the

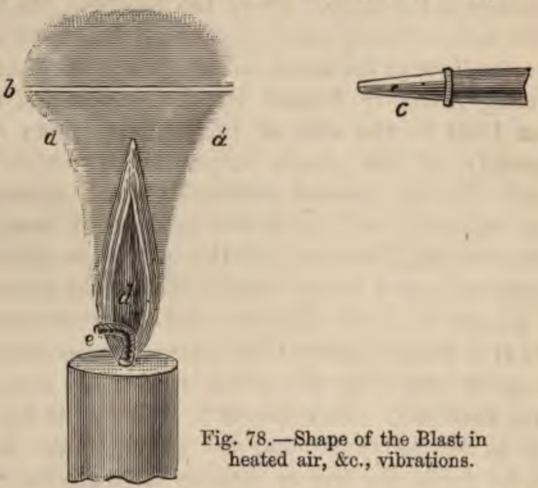


Fig. 78.—Shape of the Blast in heated air, &c., vibrations.

form *a a'*. He can no longer, of course, *see* the blast, but sees plainly that it takes the position *c b*. By holding his candle a little lower and attempting to blow *into* the blue pyrocone (in which he can't succeed) he will easily observe a dark shadow (apparently) on the upper surface of the pyrocone, which is, in reality, the mark of friction (minute waves) caused by the blast passing rapidly over it; just as a sudden, strong gust of wind passing over a perfectly calm sea causes an apparent shadow on *its* surface. It will, indeed, be evident to my students after a little close reflection (which has apparently never been vouchsafed to this matter before) that, if this fact—the non-penetration of the pyrocone by the blast—did *not* occur; in other words, if the blast could penetrate the flame, there could be no pyrocone at all; for the blast would simply bore a minute hole right through or into the candle-flame, leaving it in its perpendicular position, just as it bores a hole *b* through the heat-undulations *a a'*, Fig. 78, and as it bores a hole into the thinner consistence of a spirit-lamp flame, Fig. 80. *Conclusion or Fact.* The blast does not *penetrate* the flame as ordinarily supposed, but *produces* (Latin *pro*, forwards; *duco*, I lead), or draws forward its under or blue part in a conical shape. *Experiment* 3. The cause of this conical shape may be apparently ascer-

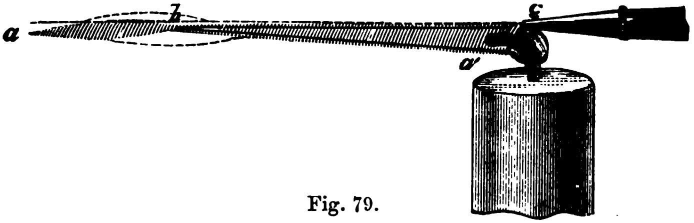


Fig. 79.

tained by a third experiment. Taking up the lighted spirit-lamp in his left hand, and the mouth-blower in his right, the experimenter now directs a blast, from about half an inch distance, into the thin matter of the right side of the spirit-flame, Fig. 80. The *shape of the blast* is now *again* observed passing into, but not quite through, this flame, which has evidently a consistence more dense than that of the heat-undulations *a a′*, Fig. 78, but less dense than the candle-flame itself, which the blast cannot penetrate at all.

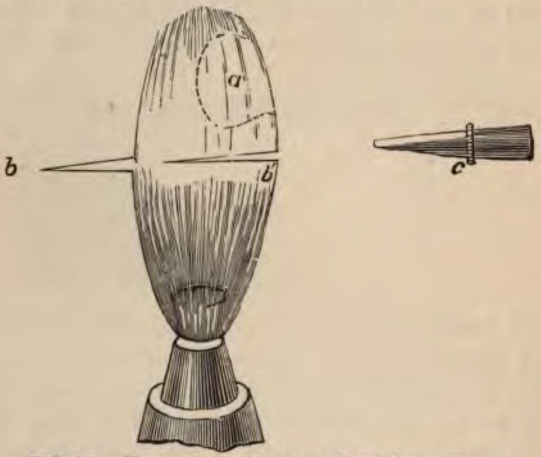


Fig. 80.—Shape of the Blast in a Spirit-lamp Flame.

The spirit-flame density, in fact, lies between these two; and, consequently, the blast-auger bores some distance only into this side, pushing or driving out of the opposite side of its viscous substance a superficial or outside image of itself, *b*, Fig. 80.

But the strange part of the matter is, that *this* blast is differently shaped from the first blast! It consists of two lines meeting in a point and forming a *cone*, whereas the first blast appears as two parallel straight lines, forming part of a needle. Now, we know it to be *absolutely impossible* that the form, or any other characteristic, of this blast should have altered, the conditions of blowing having remained precisely the same. We must, therefore, look into the *surroundings* (as I did in 1874) for the cause of this change. The conclusion I then arrived at, which still seems to me the most satisfactory one, is this; and it is the only suggestion ever offered by any writer on Blowpipe Analysis as to the *cause* of the conical shape of the blowpipe "flame."

A minute but strong current of air, like that projected from the nozzle of a blowpipe, creates *a vortex* (or small whirlpool) *in the surrounding air*. This vortex, which is of course invisible, *draws in* the impenetrable candle-flame, blown aside down to the blue part *e*, Fig. 78; turns it wholly blue (from a cause to be hereafter adverted to); and necessarily converts it to its own shape—that of a finely-pointed cone *c a′ b*, Fig. 79. It is *this* cone which forces its way into the comparatively thin spirit-lamp flame, as *b′* Fig. 80, and the gyrations (Greek *guros*, Latin *gyros*, a circle) of which, being of the same gaseous constitution as the heat-undulations *a a′*, Fig. 78, consequently combine with them, and cannot be there seen.

Now let us mark the importance of a knowledge of this fact in the operations of Blowpipe Analysis. Berzelius, who started the "theory" of "an outer and inner flame" in the blowpipe pyrocone—which is still, in spite of the incontrovertible evidence to the contrary supplied by the above-mentioned facts, employed as an "explanation" by writers on the Blowpipe—states (page 17, Whitney's translation, Boston, 1845) that "when air is forced into the flame with the blowpipe, a long, narrow blue flame appears *directly before the jet.*" This is obviously an "optical illusion" caused by the angle of depression *a i b*, Fig. 81, under which he viewed the matter. A triangle formed between the points—the plane of his eyes, the plane of the jet of his blowpipe, and his mouth whence the blast was delivered, Fig. 81, shows this clearly, although the sine of the angle *b* in the natural size is of course proportionally greater. Had he held his lamp-flame and blowpipe in the horizontal plane of vision, *i.e.* at the level of his eyes, as required in experiment 2, he would have observed the appearance of the blast and pyrocone *c b*, Figs. 79 and 86. Had he even taken advantage of the depressed angle in which he viewed his pyrocone, and looked *straight down* upon it from above, he would have got a sight which must have at once convinced a man of his talents that the blast did *not* penetrate the pyrocone. Fig. 82, which is, in fact, a *plan* of Fig. 79, shows this; *d* is the black or carbonised wick, seen through the hollow space formed naturally in all candle-flames, and shown in elevation at *d*, Fig. 78; *b* is the

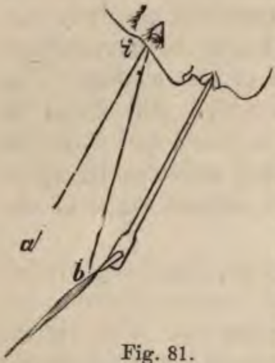


Fig. 81.

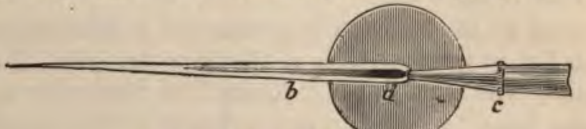


Fig. 82.—(See also Fig. 89.)

shadow-like friction caused on the surface of the pyrocone by the action of the blast, as above described, the appearance of which has evidently led to the idea of an "inner flame." Now, it is evident that the wick is here seen through the blast-space formed of a *transparent* medium like air, and *not* through a blue hydrocarbonous medium like a blowpipe pyrocone, were the blast really, as Berzelius supposed, *inside* of the latter.

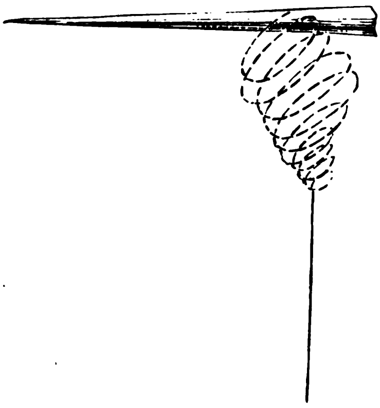


Fig. 83.

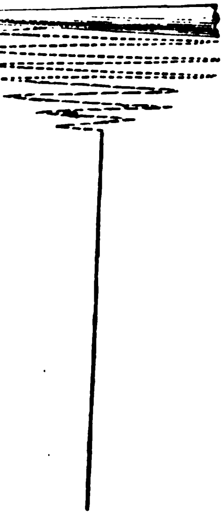


Fig. 84.

All, or nearly all, *rising* heat radiation is also stopped —evidently by the superposed blast—though not in other directions. In order to confirm the supposed presence of encircling gyrations (*c a' b*, Fig. 79) surrounding the properly-made blowpipe pyrocone, an extremely fine platinum wire (which possesses great "spring" or elasticity) is held perpendicularly to, and with its point touching one side of the pyrocone, when a series of nearly vertical ellipses are described by the point (Fig. 83), showing that it (the point of the wire) is moved by some up-and-down force like that of a nearly vertical vortex, *c a′*, Fig. 79. If, on the contrary, the motion were merely a horizontal one, as Berzelius supposed, caused by the "flame" passing from right to left, it is evident that the point of the wire would describe a series of *horizontal* zigzags, as shown in Fig. 84.

The same phenomenon can be further illustrated by holding a red-hot bead of phosphoric acid, or of lithium-carbonate, or of any volatile substance which affords a coloured flame as at *a′*, Fig. 79, or just under the base of the pyrocone, when, almost instantaneously, a "mantle" of that coloured light extends *round* the cone from the base *c a′*, to the point *b*, enveloping the whole pyrocone; whereas a straight horizontal movement would only colour the side of contact. The above proofs will probably appear to the analytical mind conclusive as to the formation of the blowpipe pyrocone by the compressing effect of a vorticose envelope of elastic heated air; but the following experiment seems to me to afford a confirmatory "clincher" of that fact. If, as Berzelius suggested, the blast penetrated the pyrocone, the superposition closely over the base of the latter, but not touching it, of a platinum capsule C, Fig. 85, would and could make no difference in the pyrocone. But what *is* the result? As soon as the capsule is so placed, the pyrocone is *instantly lengthened* from E to D! Now this result *could* only be produced by squeezing an elastic gyrating envelope of this kind, and thus reducing its basic diameter; for it is a well-known law of vorticose motion that the length of the cone is inversely proportional to the diameter of its base; or in other words, is directly proportional to the *shortness* of its basic diameter. A B, Fig. 85, represents the disc of a double (air and gas) pressure gauge or *manometer* (Greek *manos*, rarefied, and *meter*, a mea-

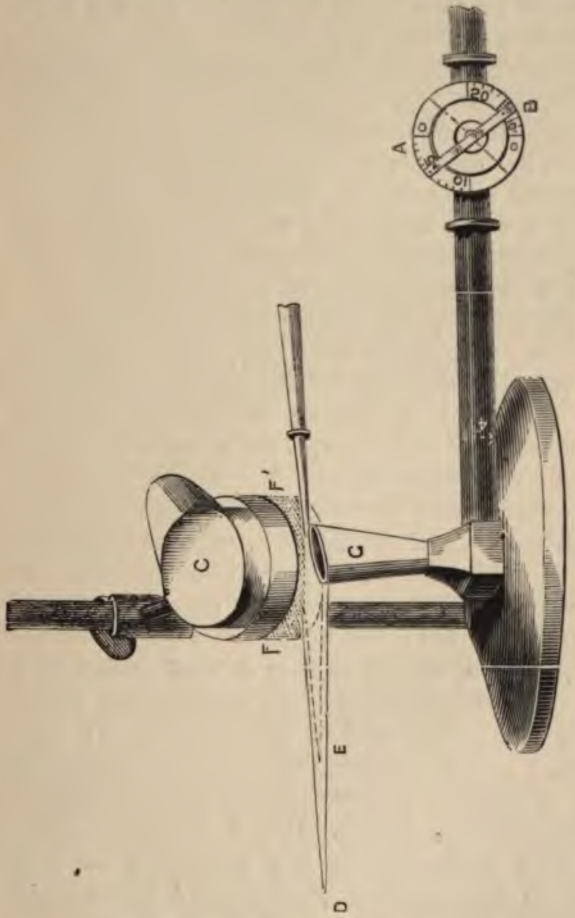


Fig. 85.—Ross's Gas and Blast Manometer.

sure); for an *exact* proportion being absolutely necessary between the air-pressure (or blast) and the gas-pressure (or flame-bulk), in order to produce a proper pyrocone; a roaring noise and broken pyrocone—proceeding from the violent destruction of the pointed end of the aërial vortex—indicate excessive air-pressure, or, popularly speaking, that "the blast is too strong;" whilst the opposite defect—excessive gas-pressure—is indicated by *luminosity;* the gas flame turning luminously upwards in spite of the efforts of the blast to keep it pyroconically horizontal. I thought, therefore, that with a supply pipe of given diameter, one end of the gas-tap, B, turning off the gas, might pass over any determined scale (say, of pyrocone-lengths) on the disc, showing the required gas-pressure; and the other end A, turning *on* the gas in order to meet an excessive blast, over a scale showing the requisite air-pressure. Such "double manometers" would apparently be useful wherever gas blowpipes are used, and a single disc might be attached to blowers for oil or candle lamps. I fear these polemical details (Greek *polemikos,* controversial) may prove tedious to the student; but it was nevertheless impossible for me to omit them, bearing as they do *most essentially* upon the proper management of the pyrocone and, therefore, upon the proper method of operating. It will be necessary now, however, to show the student how to use an ordinary mouth-blowpipe not provided with a valve, like that in Fig. 3; and this can apparently be done without using any anatomical expressions, such as the "musculi buccinatores" (cheek-muscles) of some authors (Trans. Plattner, p. 10). Get a lighted candle (Fig. 78) and a common mouth-blowpipe; apply the thick end, or trumpet mouthpiece, of the latter to the nearly closed lips, and the thin end to one side of the candle-flame; puff out the cheeks and blow through the blowpipe on the candle, breathing through the nose strongly and audibly all the time; when the breath in the cheeks begins to be exhausted, pronounce the word *cow* in your throat without opening your mouth, by which pronunciation you will find your cheeks puffed out again, or, in other words, the cheeks replenished with breath as an air-reservoir.

The student has now, fairly and honourably, by rational argument alone, arrived at the logical conclusions (*a*) That the action of the blowpipe upon the flame of a candle or lamp produces, not "outer and inner flames," but only one *solid* cone of blue-fire, which, as it is obtained from a hydrocarbon (this word will be explained in another part of these "lessons," but all oils, candles, or coals are "hydrocarbons"), must be composed of hydrocarbonous matter in a state of ignition; and (*b*) That this hydrocarbonous pyrocone is closely surrounded or enveloped by gyrating, strongly-heated atmospheric air, which contains a gas called *oxygen* (another chemical term to be afterwards explained). It is this "oxygen" that forms what chemists call *oxides* (but which I have ventured to call *pyroxides*, as they are here produced by the direct action of fire) on the surface of solid, but also in the interior, of very fluid assays. Now, it is evident, from the picture Berzelius gives of what he calls the "outer and inner flames," that (betrayed by his scorn for blowing apparatus), the blast he produced from his mouth blowpipe was not duly proportioned to the bulk of the flame he produced from his oil-lamp, or, popularly speaking, "was not strong enough for it." He only blew the flame feebly on one side, and, consequently, left what he called "a brilliant part"—a part altogether discarded by later writers, as Fresenius, and Landauer, of Brunswick, neither of whom show any "inner flames" in their pictures of pyrocones. Landauer, indeed, draws a pyrocone precisely as I myself would draw it, and even exaggerates my view, by showing a too-dark shadow or "ripple-mark" of the blast-friction *on the surface* of his blue pyrocone. When Berzelius developed the idea of the blast being *inside* the pyrocone, it was, of course, necessary to modify the logical (and true) conclusion of his teacher, Dr. Gahn, and of the celebrated chemist, Bergmann, who both asserted that the interior of the blue pyrocone is the proper position for holding an assay, if you wish to deprive the latter of oxygen, or to "reduce" it, for it is obvious that, if it be admitted that this cone is filled with air by the blast, and, therefore, contains oxygen, such a position would never *deprive* an assay of oxygen; Berzelius, therefore, without a shadow of or attempt at reasoning in support of his assertion, dogmatically states: "The blue flame was formerly regarded as the proper reducing flame; this is, however,

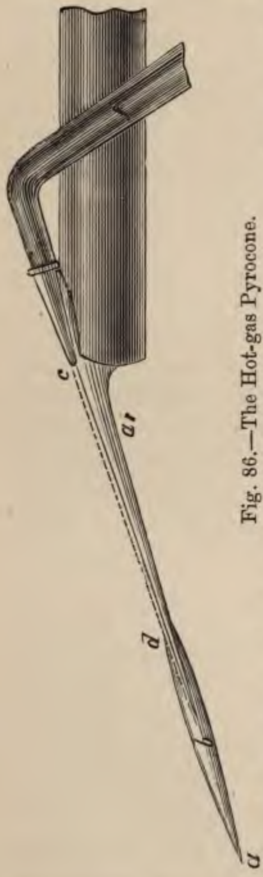


Fig. 86.—The Hot-gas Pyrocone.

untrue, for it is the brilliant portion of the flame which causes deoxidation."

When a *proper* pyrocone is formed then—that is, when the blast is exactly proportioned to the bulk of flame—whether of oil, candle, or gas-lamp; but we shall take the last-mentioned of these as our example at present—it has the shape *c á b* (Fig. 86), the extremely fine point *b* being enveloped in a nearly invisible pale-violet ellipse, *d b a,* of gases containing oxygen, due, as I believe, to the fact mentioned by Sir John Herschel ("Meteorology," p. 67), that "a vorticose motion in air recommences when finished, in the reverse direction to what it had before," the *rationale* (or reason) of which will be seen by referring to Fig. 79, *b a.* The fact can also be exemplified by sending, with a mouth-blower, a blast from a distance equal to the whole length of the first vortex, into a spirit-lamp flame, when the shape of a blunt *inverted* cone is impressed on the flame (*a,* Fig. 80). It is evident, therefore, that if we hold an assay at *b,* Fig. 86, it will not only be intensely heated, but chemically treated by dense air, which is a *mechanical* compound, containing oxygen, and by hydrogen, for the carbon-gas or carbon monoxide, (another word to be explained afterwards), to which the blue colour is partly due, must be considered to have been consumed in the passage from *c* to *b.* This point of the pyrocone is, therefore, called the oxidating or oxydising flame—in brief, O.F.—by former writers; but to suit my views, I have slightly altered the symbol to O.P. for "Oxy-hydrogen Pyrocone." The position just beyond *a,* the extreme point of the secondary or violet cone, *a b,* has been omitted by former writers (except Landauer, who has adopted it from me); but finding it to possess extraordinary oxydising properties (the hydrogen having been nearly consumed), which often are extremely useful, as in the case of testing sublimates deposited on aluminium plate, I have given it a symbol, P.P., for "Peroxydising Pyrocone." The so-called "Reducing Flame," or R.F., is simply the gas or candle-flame treated with less air-pressure or a feebler blast, when, of course, a short vortex with large basic diameter is produced, but still not so feeble as that whereby Berzelius merely turned his "brilliant" lamp-flame on one side. This has the effect of producing a large, blunt pyrocone, *g h*, the outline in Fig. 87, which must be wholly blue, without any trace of luminosity in it. It has been proved to be solid, and being composed of hydrogen and carbon, without a particle of oxygen, has tremendous "reducing" power; a bead of glacial phosphoric acid itself, carefully held there at *g* for a few minutes, having a white, shining, metallic-looking crust composed over its surface, which can be picked off by forceps. Any position within this blue pyrocone, therefore, has been symbolised by me H.P. for "Hydrocarbonous Pyrocone," instead of R.F. for "Reducing Flame"; because, in the first place, many effects besides "reduction"—such, for instance, as colouration of beads, and fire-colouration—are produced by this position of the assay; and, secondly, the action of ignited hydrogen gas upon the assay, which exerts at least as much chemical effect upon it as oxygen—though strangely omitted by all writers on Blowpipe Analysis—has due

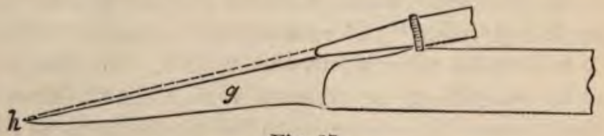


Fig. 87.

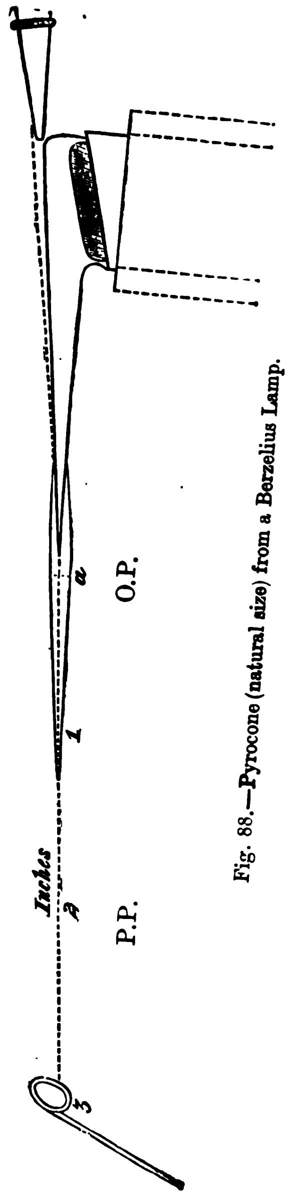


Fig. 88.—**Pyrocone (natural size) from a Berzelius Lamp.**

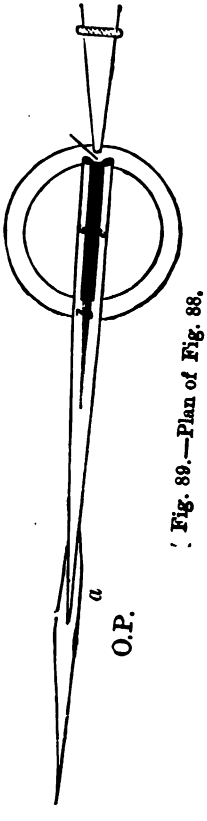


Fig. 89.—Plan of Fig. 88.

acknowledgment in this name. Figs. 88, 89, and 90 represent these pyrocones obtained from a Berzelius oil-lamp. *Recapitulation.*—It must be remembered, then, that

Any position within "the blue,"
as *g* Fig. 87, and Fig. 90 = H.P.
„ from *b* to *a*, Fig. 86 . . . = O.P.
and „ at or beyond 1, Fig. 88 . . = P.P.

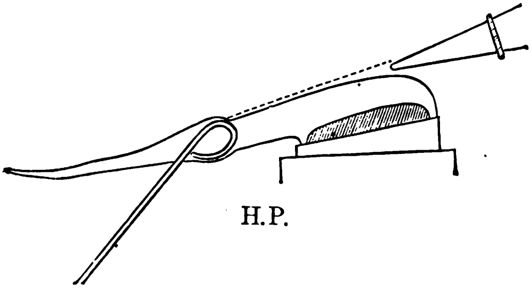


Fig. 90.

CHAPTER VI.

ON PYROLOGICAL REAGENTS.

BERZELIUS tells us that "Cronstedt used only three reagents: soda, borax, and salt of phosphorus, devised by himself. These reagents are still in use, and among the great number of those which have been tried since, not one has been found to replace either of these. It is singular enough that in the very beginning of this science, the very best reagents should have been hit upon." Singular indeed! But the fact is, this often-quoted remark is quite unworthy of the deservedly celebrated writer: not less on account of the utter disingenuousness of its premises, than by reason of the entire carelessness (if not worse) of its conclusions. For Berzelius, in charge of the archives of the Academy at Stockholm, knew very well that in 1737, or twenty-one years before Cronstedt wrote *anything*, Cramer at Leyden had described exactly what Berzelius miscalled "Cronstedt's Blowpipe," with a hollow ball in the centre, and had mentioned that he (Cramer) then used borax and soda as fluxes (Margraff, of Berlin, having described "phosphor salt" afterwards), most certainly by the directions of the inventor of the chemical blowpipe *Von Svarb*, whose writings are (as Cronstedt himself mentions), also "deposited" or hidden in the Stockholm Academy. Yet Berzelius has the conscience to write, or prevaricate, "Antony von Svarb published nothing upon this subject, and it is not known to what extent he carried his researches!" But Cronstedt was a Swedish nobleman, whose family Berzelius "delighted to honour;" and Von Svarb only a "common" miner and "nature's nobleman." The student of Blowpipe Analysis will soon see, from what follows, either that Berzelius could not have tried other reagents, as he says he did; or that his powers of observing and assimilating facts have been extremely over-rated.*

Borax and Boric Acid† as Reagents.

(1) Both of these (about the same price—viz., 3d. per ounce, borax being generally in powder, and boric acid in white scales; if ready fused, which is not much more convenient, 1s. per oz.), are treated in the same way on the platinum wire ring support (Fig. 37), in O.P., by taking up a little at a time from the agate slab with the red-hot ring, until a transparent colourless bead is produced in each case; borax, after a little intumescence or swelling up, fuses at once; but boric acid being very viscid, retains bubbles of air, steam, or other gases, which are with difficulty expelled; and this fact, which seems merely an inconvenience to the careless "observer," is, in reality, of very great importance

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* It will be apparent to any competent investigator who has the leisure and patience to collate the requisite works at the British Museum, that Berzelius only compiled or edited the first part of the work on the Blowpipe which bears his name; the real author being undoubtedly his teacher, Dr. Gahn. The work was published in 1820, Gahn having died in 1819! It is now well known, also, that Gahn was the real (and, indeed, the admitted) author of the work on the Blowpipe attributed to, and appropriated by, Bergmann; first published in a German translation by Baron Born, at Vienna. A *true* history of Blowpipe Analysis would expose some very queer facts regarding the scrupulosity of these and other "celebrated chemists." Von Svarb, Gahn, Harkort, and Plattner were the only *really original* writers on the Blowpipe.

† Introduced by the Author in 1869.

and value in showing the analyst, by the phenomenon called "effervescence," the presence of carbonic-acid gas (termed by chemists "carbon dioxide"), and *also* of sulphuric acid (as in "green vitriol" or "copperas") in the assay when added to the bead in powder and treated by O.P. borax in such cases and conditions shows *nothing*, but merely dissolves the added powder without effervescence; nitric or hydrochloric acid would effervesce with a *carbonate* (or assay containing carbon dioxide), but *not* with a sulphate (or assay containing sulphuric acid); hence boric acid and a blowpipe in such cases are really invaluable, for another simple test soon distinguishes the two. (2) Borax being a compound of boric acid and soda, called by chemists "an abnormal sodium borate" (Valentin), the beautiful green pyrochrome afforded by pure boric acid before the blowpipe, is completely obscured and "swallowed up" by the "stronger" yellow, or rather orange, pyrochrome of sodium, which also obscures any pyrochrome of substances or assays added to its bead; but this is not the case with regard to substances treated in boric acid; some of which, as copper, modify or alter the green colour of its pyrochrome to a surprising extent, enabling themselves thus to be detected in infinitesimally minute quantities. There is no other method, either in the "wet" or "dry" way (unless it be the spectroscope), which can detect with such certainty, such a minute trace of copper in a substance as this method can; whilst, as exactly 5 per cent. of soda completely obscures the green pyrochrome of an ordinary pure boric acid bead, and turns it yellow, the operator here approaches a quantitative analysis (Latin *quantitas*, quantity) as regards the *amount* of soda present. (3) Scarcely any substance except platinum, and that class of metals, can be added to a borax bead in O.P., which is not immediately and wholly dissolved: if the substance be chromatic (Greek *chroma*, colour), and afford a coloured bead, it can certainly be thus detected by borax; but only at the (very serious) price of preventing the detection of any other oxide or substance present with it in the mineral or assay which does not thus afford a colour, or which affords a colour inferior in brightness or depth to the other, and is thus obscured or "swallowed up" by it. Thus, in a qualitative assay by the blowpipe of the common mineral *Smaltite*, which is a compound of the metals iron, nickel, cobalt, and a trace of copper, with arsenic, after the arsenic has been "driven off by roasting," as much as possible, the remaining powder applied to borax before the blowpipe, affords only a blue transparent bead, hot and cold, which, even flattened on an aluminium plate and examined through a lens, is still only a blue bead. When this powder, on the contrary, is applied to a bead of boric acid under like conditions, the above-mentioned metals, which have now been changed by "roasting" on aluminium plate, from "arsenides" into "oxides," are seen to remain in the bead, *utterly insoluble*, both by any further action of the blowpipe, and in boiling water afterwards; to be *separated* in the bead from each other as easily distinguishable, or totally different forms; to "impart" no "characteristic colour" whatever "to the mass" or bead;* and finally, to be each so acted upon whilst in this separate state in the bead, by O.P. or H.P., as to slightly change its appearance, and thus afford fresh evidence for the detection of most of these insoluble "borates." A comparison of Figs. 91 and 92 will render this different action of borax and boric acid upon "oxides" added to them before the blowpipe, sufficiently clear to the dullest student.

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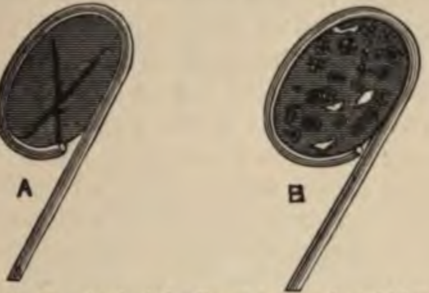
* In allusion to the erroneous idea entertained by some chemists, that—"Most metallic oxides dissolve in fused boron trioxide at a red heat, many of them imparting to the mass characteristic colours; hence this substance is much used in blowpipe analysis." (It was *never* used in this way before I did so.)



Figs. 91, 92.—Analysis by Borax and Boric Acid beads.

A (Fig. 91) is a bead of borax on a platinum wire ring, to which a trace of well-roasted *Smaltite* powder has been added in H.P.; as colours cannot be shown here, the Andrew's cross represents *blue*, a perpendicular cross represents *violet*, a dot in the centre of an object represents *brown*, perpendicular parallel lines *green*, and so on. B (Fig. 92) is a bead of boric acid, to which a trace of the same powder has been added under similar conditions; both are supposed to be viewed through a lens. Mark the difference! Instead of a jumbled solution of everything, in which any colours possibly given to the bead by other oxides are completely overwhelmed in blue, the colour bestowed upon it by cobalt, even if the latter were only one-fiftieth the quantity of the others; we find the *cobalt* present simply taking its place in the bead with other separated borates, as opaque, violet balls (those with perpendicular crosses in B; the balls should be *perfect* sphericles, and not as they are represented in the figs.); the trace of *copper* present is at once perceived by the brilliant blue-green, luminous pyrochrome, which instantaneously replaces the non-luminous yellow-green one always afforded by the bead itself, *and* by the one or two minute, black, opaque balls with coppery suffusion round them, seen in the left of B. The (generally) large percentage of *iron* is readily perceived by the proportionately numerous brown, opaque balls (those with a dot in the centre) surrounded by a rust-like matter; and finally the proportion of *nickel* is surmised, and its presence easily ascertained, by the appearance here of a few *green fragments* (seen to be definite crystals in a microscope), which have been turned white, with a metallic lustre, by H.P., excepting one on the left, which has happened to remain green; it must be remembered that the whole of these reactions are developed in *one trace* of the powder. Besides these indications, *combined*, or chemical *water* in the mineral, is shown (almost quantitatively) by a *grey opalescence* pervading the whole bead; an indication not apparently afforded by any other method of analysis "wet" or "dry." When this "combined water," which can be proved to exist in every known mineral, even in the so-called "anhydrates" (Greek *an*, without, and *hudor*, water) and in *rock crystal*, that is, "pure" silica, renders the boric acid bead so opaque that the contained balls and fragments, &c., cannot readily be perceived even through a lens, the process of "vesiculation,"—or blowing the small bead as a glass-blower would, into a comparatively large "vesicle" or bladder—must be resorted to; or else the bead must be boiled in distilled water, and the insoluble contents treated in a fresh bead—a much longer and more tedious affair. This process, devised by me in 1867, is very easy, and almost as amusing as "blowing soap-bubbles," for the vesicles are extremely thin, and therefore possess the same iridescent colours, consequent upon light "interference;"—it would not, however, be fair to mention the distinguished philosophers I have thus seen "blowing bubbles" at my house! The operator must have a spare mouth-blowpipe, from which the nozzle (B, Fig. 1) has been removed, ready at his right hand; the bead is taken, red-hot from O.P. by the left hand, and a moderate but rapid blast sent through the platinum-wire ring from the jet (A, Fig. 1) before it cools. Fig. 93 (natural size) is something like the result, only very much larger vesicles than this will be blown, especially by the beginner. It will be evident from a synchronous (Greek *sun*, together, and *chronos*, time) or simultaneous examination of Figs. 92 and 93, that these insoluble borates can be very much more easily per-

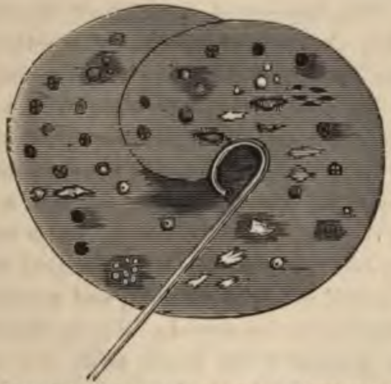


Fig. 93.—A Vesicle showing 16 separated Borates (natural size).

ceived and identified in the vesicle than in the bead. Vesicles are also chemically useful, as in detecting traces of *fluorine*, and in the detection of certain gases, as H_2S., facts to be afterwards explained with reference to this Fig. If these separated borates (with the exception of the chemical-water borate) are desired by the operator so as to be weighed separately in an "assay balance," all he has to do is to throw the bead, or quicker still, the vesicle, wire and all, into the little capsule, full of boiling distilled water, which he has ready (H, Fig. 21). The boric-acid bead itself is rapidly thus dissolved, but the insoluble borates, whether in balls or fragments, are found at bottom of the capsule, and can be obtained dry by first carefully decanting a portion of the water, and then upsetting the capsule upon a pad of clean white blotting paper, whence the dried borates may be picked up with forceps, or brushed with a small hair pencil into the pan of the balance. They can also be obtained by decanting and adding distilled water until no free boric acid is left in solution, and gently evaporating the water left in the capsule. Surely these enormous advantages possessed by boric acid, far more than counterbalance its single disadvantage of not being quite so easily fusible before a mouth-blowpipe as borax is? As this is intended to be a complete treatise on the elements of blowpipe analysis I shall nevertheless, where such a course is useful, detail the blowpipe reactions of borax, &c., with minerals, selected and condensed from the notes of some of the best workers at Freiberg University; and it must be remembered by the student that he has only to add the proper proportion of soda before the blowpipe, in order to convert his boric-acid bead into a bead of borax, and thus obtain all *its* reactions afterwards, in addition to those previously obtained, of the former. Thus, if he fuses on bead B, the proper amount of soda in O.P., so as to melt the whole of its contents together, it is obvious that he will obtain a simple blue bead as A. He, therefore, need not take borax with him on his travels, but only boric acid and soda separately, wherewith to make borax afterwards, and thus obtain its colour reactions.

The following Table, by one of our most accomplished chemists, of the "bright" or flame-lines afforded by some important substances to the spectroscope, will be found most useful to those who can afford to purchase that instrument. Fig. 94 is a "Spectrum Lorgnette," by means of which a small spectroscope (made by Browning of the Strand, London) may be attached to the head like a pair of spectacles, and the lines thus observed by the operator while he is producing them with his blowpipe.

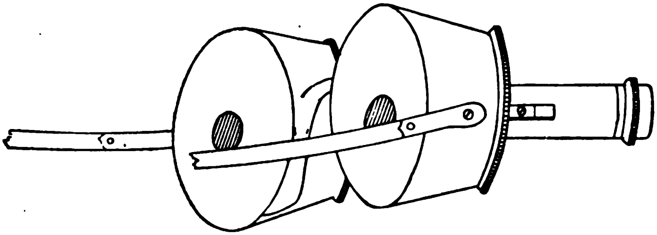


Fig. 94.—Ross's Spectrum Lorgnette.
(Introduced in 1874.)

Table I.—Spectrum Lines of the most important Flame-colouring Elements.

By Prof. Roscoe, F.R.S.

Elements.	Red Lines.				Orange Lines.		Yellow Lines.	Green Lines.			Blue Lines.				Violet Lines.			
0	10	20	30		40	50	60	70	80	90	100	110	120	130	140	150	160	170
Sodium .	..	..	..	..	..	50												
Potassium .	..	17	27	..	..	..		..	..	..	..	..	..	..	..	..	153	
Lithium .	..	..	..	31	..	45												
Cæsium .	..	..	27	31	38	41	51;56 57	62;63 66;68 69	71	..		106 109						
Rubidium .	..	13;15	..	..		40;42 43;45	55;57	65;67	71;73 76;78		..	..	..		135 137			
Barium . .	..	..	..	35	39	41;43 44;45 47;50	52;55 57	61;67	71;77	90								
Strontium .	..	..	30	..	36 38	42;45	..	..	..	..	..	105						
Calcium .	..	..	..	32 34	37	42;46 49	52;55	62	..	..	..	..	..	..	135			
Thallium .	..	..	..	..	..	..	..	67										
Indium .	..	..	..	..	..	..	..	..	..	..	..	..	111	..	..	147		

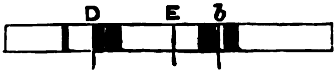


Fig. 95.

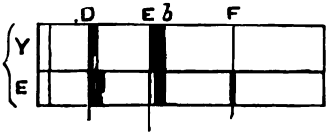


Fig. 96.

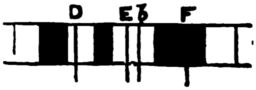


Fig. 97.

Spectroscope Lines or "absorption bands" in Ca Borate Balls.

Fig. 95	Didymium.
„ 96	Yttrium and Erbium.
„ 97	Uranium.

N.B.—Lines of the Solar Spectrum are prolonged.

How to obtain Absorption Bands.

Spectroscopic dark lines (Figs. 95, 96, and 97), or "absorption bands" (so called from the supposed absorption of the light examined, leaving a shadow or dark hiatus in its place) are obtained as follows: The assay, except for Cerium, Didymium, and Lanthanum, which themselves form clear balls in B. acid, is made of a calcium borate ball the size of a largish pin's head, extracted from its bead by boiling. The ball having the substance dissolved in it, is taken between the points of forceps, Fig. 40, and held there by slipping up the band which keeps the legs together. The forceps, having the ball between its legs, is placed with its hilt inserted between the leaves of a thick book, placed standing on an end on a table, with the back towards the examiner, so that the forceps stands upright, and with the ball, may be slanted towards or from him, as may transmit the greatest amount of light from a window, open if possible, in front.

Table II.—Useful Contractions and Symbols.

A Bead	The *largest* amount of flux fusible on a wire ring of given diameter.
A Glass	„ *smallest* ditto, ditto, ditto.
Al Plate	For Aluminium plate.
Al_2O_3	„ Alumina.
Ag_2S	„ Sulphide of silver.
As_2O_5	„ Arsenic acid.
As_2O_3	„ White arsenic. Arsenious oxide. Sublimate of arsenic.
B. Acid	„ Boric acid.
Bd.	„ Bead.
B_2O_3	„ Boron trioxide. (Boric acid.)
BaO	„ Baryta. Oxide of barium.
Blk. Blkg	„ Black. Blackening.
B. B.	„ Before the blowpipe.
BeO	„ Oxide of beryllium or glucinum.
Bi_2O_3	„ Bismuth trioxide.
C	„ Charcoal.
CaF_2	„ Fluorspar.
CaO	„ Lime.
CaB_2O_4	„ Calcium borate (lime balls).
Carb.	„ Carbonate.
Col.	„ Colour.
CoO	„ Oxide of cobalt.
Cop.	„ Copious.
Co_2	„ Carbon Dioxide. Carbonic acid gas.
CuO	„ Oxide of Copper (black).
Cu_2O	„ Suboxide of copper (red).
c/c	„ Per cent.
Darkg.	„ Darkening.
Dec.	„ Decomposed.
Decrs.	„ Decrepitates.
Diss.	„ Dissolves.
DiO	„ Oxide of Didymium.
Effec.	„ Effervescence.
Effs.	„ Effervesces.
ErO	„ Oxide of Erbium.
E. P. (or "Mantle")	„ Ellychnine pyrochrome (Greek *Eleuchnion*, a wick) made by touching the wick with the hot assay. Colours the whole pyrocone.
FeO	„ Iron monoxide.
Fe_2O_3	„ Iron sesquioxide.
Fragts.	„ Fragments.
G.B.	„ Glass bulb.
GlO	„ Oxide of beryillium and glucinium.
HgO	„ Red Precipitate.
H_2O	„ Water.
H_2O_2	„ Hydroxyl, or hydrogen peroxide.
HF	„ Hydrogen fluoride. Hydrofluoric acid.
HNO_2	„ Nitric acid.
H_2P	„ Hydrogen phosphide. Phosphuretted hydrogen.

H_3N	For Ammonia.
H_2S	,, Hydrogen sulphide. (Sulphretted hydrogen).
H_2SO_4	,, Sulphuric acid.
H.P.	,, Hydrocarbonous pyrocone (old R.F.).
Ins	,, Insoluble.
Irid.	,, Iridescent.
$KHCO_3$	,, Potassium carbonate. "Potash."
$KHSO_4$	,, Acid potassium sulphate.
Li_2O	,, Lithium oxide. Lithia.
Mag.	,, Magnetic.
Metc.	,, Metallic.
MgO	,, Magnesia.
MoO_3	,, Molybdenum trioxide. Molybdic acid.
Na_2CO_3	,, Neutral Sodium carbonate. "Soda."
O.P.	,, Oxyhydrogen pyrocone (old O.F.)
Op.	,, Opaline.
Opq.	,, Opaque.
p.c.	,, Pyrochrome.
P.P.	,, Peroxydising pyrocone. (No old name.)
P.B. acid	,, Phosphoboric acid.
P. acid	,, Phosphoric acid.
P. salt	,, Phosphor salt.
Prop.	,, Proportion.
Pt. wire	,, Platinum wire.
Red.	,, Reduced.
Redh.	,, Reddish.
Satd.	,, Saturated.
SiO_2	,, Silica. Silicic acid. Quartz.
Soln.	,, Solution.
SO_2	,, Sulphurous acid. (Sulphur "Fumes.")
Sp. gr.	,, Specific gravity.
Subt.	,, Sublimate.
Suffn.	,, Suffusion.
Temp.	,, Temporarily.
Thr.	,, Through.
TiO_2	,, Titanium dioxide. Titanic acid.
Transp.	,, Transparent.
U_2O_3	,, Uranium trioxide.
Vg.	,, Vanishing.
Vol.	,, Volatilised.
VO_3	,, Vanadium trioxide. Vanadic acid.
Wht.	,, White.
WO_3	,, Tungsten trioxide. Tungstic acid.
Yel.	,, Yellow.
ZnO	,, Zinc oxide.
ZrO_3	,, Zirconium trioxide. Zirconia.

Following is a table (III.) to which the student will often have to refer, and which explains itself, of the reactions of pure oxides in boric acid, supposed to be viewed through an ordinary lens.

Table III.—Reactions of Pure Oxides in Boric Acid.

Atomic Weight.	Names of Elements.*	Under O.P.	Under H.P.	Remarks.
27·5	Aluminium ... Al	White opaque fragments, rounded edges	do.	Evolves milk-like matter, with calcium-borate balls O.P.†
122·	Antimony ... Sb	An ice-like mass ...	do.	See aluminium plate reactions.
75·	Arsenic ... As	Brownish-white matter ...	do.	Do. do. do.
137·	Barium ... Ba	Transparent balls evolving thick opaque matter† ...	do.	Green pyrochrome *per se.*
	Beryllium ... Be	See Glucinum		
208·	Bismuth ... Bi	Rust-like flocculent matter† ...	do.	See aluminium plate reactions.
11·	Boron ... B	Nil ...	Nil.	Tested for by phosphoric acid, titanic acid, soda, and drop of water.
112·	Cadmium ... Cd	Transparent colourless balls, with reddish woolly matter† ...	Reddish.	See aluminium plate reactions.
40·	Calcium ... Ca	Transparent colourless balls, decomposed by alumina† ...	do.	Red-orange mantle-pyrochrome E.P.†
12·	Carbon ... C	Effervesces as CO_2. Green p.c. temp. yellowed† ...	do.	Black stain with SO_2 after H.P., on silver.
94·5	Cerium ... Ce	Brown transparent balls ...	do.†	Di. spect. lines *per se*, and in Ca borate balls.
35·5	Chlorine ... Cl	Blue p.c. with copper oxide (Cu oxide red. to metal)† ...	do.	A choking smell.
52·5	Chromium ... Cr	Green opaque fragments ...	do.†	Diss. by Na O.P. to green bead, pink, hot.†
58·8	Cobalt ... Co	Black opaque balls ...	Violet opaque†	Diss. by Na O.P. to pink bead, blue, hot.
63·5	Copper ... Cu	Blue-black opaque balls ...	Coppery suffusion.	Instantaneous blue-green pyrochrome.†
96·	Didymium ... Di	Pale violet transparent balls ...	do.	Lines in spectroscope. (Fig. 95.)†
112·6	Erbium ... Er	White opaque fragments, balls after long O.P.† ...	do.	Spect. lines in Ca borate balls. (Fig. 96.)†
19·	Fluorine ... Fl	Effervescence, with choking smell ...	do.	Vesiculated & breathed on, a green light [O.P.†
9·2	Glucinum ... Gl	White opaque fragments ...	do.	Unaltered by lime-balls in O.P.†
196·7	Gold ... Au	Yellow metallic ball ...	do.	See Al plate reactions.
1·	Hydrogen ... H	Opalesct. matter as chemical water ...	do.	An orange pyrochrome.
56·	Iron ... Fe	Brown opaque balls with rust-like matter	do.	Green protoxide with lime-balls O.P.†
94·2	Lanthanum ... La	Bluish transparent balls† ...	do.	Didym. spect. lines, *per se*, and in Ca borate balls. (Fig. 95.)
207·	Lead ... Pb	White opaque matter (oxide) ...	do.	With sublimate, a transparent bead.
7·	Lithium ... Li	Dissolves cobalt balls to pink ...	do.	Green p.c. made violet by 5 per cent.†

24·	Magnesium	Mg	White opaque balls, transparent, after long O.P.†	do.	Makes lime-balls opaque while hot.†
55·	Manganese	Mn	Brown transparent balls	Colourless.†	Tested by P acid, blood-red bubbles, O.P.†
209·	Mercury	Hg	Nil	do.	In glass bulb, whitens gold-leaf (sp. lamp).
96·	Molybdenum	Mo	Black opaque fragments	do.	On add. of P acid H.P. a green bead.
58·8	Nickel	Ni	Green opaque fragments	White metallic.†	Diss. by Na, O.P. to brown bead.
94·	Niobium	Nb	Buff-coloured opaque fragments	do.	Diss. in Ca borate O.P. to brown ball O.P.†
14·	Nitrogen	N	An amethystine bead with MnO_2 and potash treated in H.P.†		
197·4	Platinum	Pt	Infusible	do.	Fused with P acid on charcoal, O.P. to cryst. ball.†
39·	Potassium	Ka	Dissolves cobalt balls to pink suffn. blue, hot	do.	Green pyrochrome unaltered.†
31·	Phosphorus	P	Opaline bead with 2 p. cent. of free P_2O_5	Colourless hot.	On add. of tungstic acid H.P. a blue bead.
79·4	Selenium	Se	Smell of rotten horseradish H.P.†	do.	See Al plate reactions.
28·5	Silicon	Si	White sharp-angled fragments	do.	Grey opalesct. matt. with lime-balls O.P.†
108·	Silver	Ag	Yellow creamy streaks with reddish spots	Tortoise shell-like	See Al plate reactions.
23·	Sodium	Na	Diss. cobalt balls to pink suffn. blue, hot	do.	Green p.c. completely yell. by 5 per cent.†
87·5	Strontium	Sr	Transparent colourless balls melted transparently by alumina†	do.	Orange-red mantle-pyrochrome E.P.†
32·	Sulphur	S	Effervesces as SO_3, Green p.c. unaltered†	do.	Bl. stain with C, on silver, with CuO, O.P. green transpt. balls.†
137·5	Tantalum	Ta	Brown opaque fragments	do.	Diss. in Ca borate to brown ball O.P.
128·3	Tellurium	Te	Curious smell H.P. like horseradish	do.	See Al plate reactions.
204·	Thallium	Tl	Nil	do.	See Al plate reactions.
231·4	Thorium	Th	Yellow opaque fragments	do.	
118·	Tin	Sn	Yellowish white opaque fragments	do.	See Al plate reactions.
50·35	Titanium	Ti	Yellow opaque fragments	Blue, opaque.†	With Na H.P. diss. to amethystine bead.
184·	Tungsten	Wo	Black opaque fragments	do.	On add. of P. acid, H.P. a blue bead.†
120·	Uranium	U	Minute black opaque fragments	do.	With Na H.P. diss. to green bead. Lines in spect. (Fig. 97.)†
137·1	Vanadium	Va	Black opaque fragments, forming balls after long O.P.†	do.	Diss. by Na H.P. to dark bluish-green bd.†
61·7	Yttrium	Yt	White opaque fragments	do.	Diss. in lime balls O.P. Fnt. lines in spect. (Fig. 96.)†
65·	Zinc	Zn	Semi-transparent small balls, with op. matter, like boiled sago†	do.	See Al plate reactions.
89·5	Zirconium	Zr	White opaque fragments	do.	Evolves opaline matter *per se* in O.P.†

N.B.—Soft Minerals, forming fragments only, should be fused with soda on Al plate, and the boiled and dried residue treated in B. acid O.P., to test for phosphates or sulphates.

* These, with their contractions, should be committed to memory by the student. † A very distinctive reaction.

The student, having carefully studied the preceding table, blowpipe in hand, with what chemically pure oxides he can procure, will be in a position to proceed to the consideration of other less important reagents.

CHAPTER VII.

ON REAGENTS AND SIMPLE MINERAL ANALYSES—"GLACIAL PHOSPHORIC ACID," AND PHOSPHOR-SALT AS REAGENTS.*

PURE phosphoric acid is so deliquescent (Latin *deliquesco,* I dissolve), that is, absorbs moisture from air, that it cannot be moulded into blocks or shapes as generally supposed, so as to remain solid for any length of time, even in a well-stoppered bottle. What we in this country receive from Germany as sticks of "glacial phosphoric-acid" contains, therefore, about (I do not know the exact quantity) 10 per cent of soda, to enable the makers to "cast" it in sticks; without soda it is also too volatile to make a bead. The well-known English manufacturing chemists, Messrs. Hopkins and Williams, of Hatton Garden, have cleverly attempted to remedy this defect by manufacturing ammonium-phosphate, from which the ammonia might be presumed to be volatilisable (Latin *volatilis,* flying) by heat, leaving pure phosphoric acid behind, and they were so kind as to give me a little to try with the blowpipe; but I found, as Mr. Williams pointed out, that a certain proportion of the ammonia cannot be volatilised *per se,* so that it is really a matter of serious doubt whether in microcosmic salt (now called phosphor-salt, which is a double phosphate of sodium and ammonium), "the ammonia is wholly volatilised, leaving sodium metaphosphate behind," as chemists assert.

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* Introduced by the Author in 1869.

But in any case, the *stick* "glacial" P. acid (the acid sold in blocks or masses will *not* do for these purposes), especially if the hot bead is dipped into *pure* deliquesced phosphoric acid before use, is an immense improvement upon P. salt as a blowpipe reagent, whilst fusing quite as easily B.B. on platinum wire, for the following reasons: (1) Instead of the eternal "blue, hot, and cold," which P. salt as well as borax affords with any proportion of oxide of cobalt in O.P. and H.P., glacial P. acid produces, with the minutest trace of that oxide, a *faint pink* colour, which is blue hot; with more oxide, a magnificent *red violet* (quite equal to the beautiful aniline dye of that tint), which is also blue hot. Now, if my estimate of the natural acuteness of English artisans is correct, my pupils will have already surmised the advantage of using a reagent which, evidently, the *addition of an alkali* (for P. salt contains far more alkali than "glacial" P. acid does), converts from pink or red, into blue. In short, it is evident that if you treat any mineral powder containing the alkalies potash, or soda, or lithia, as a constituent, in a thus-made pink P. acid bead in O.P., the rapid solution of the alkali in the bead will turn it to a bluish violet, blue violet, or blue colour, on cooling; of a depth or faintness of "tone" proportioned exactly to the *quantity* of alkali contained in the mineral. In fact, this pink bead is a little alkalimeter in itself. (Arabic *al-kali, alkali,* the reverse of acid; and Greek *metron,* a measure.) (2) The two "earths," silica and zirconia, are *entirely* insoluble in a P. acid bead when treated with P.P., and nearly insoluble in O.P. of a hot gas lamp, especially when the bead is dipped in pure phosphoric acid, whilst every other oxide is, more or less rapidly, thus dissolved. So treated, it forms an excellent reagent, not only for detecting silica in any combination, but for giving you some idea of the *quantity* present, after your judgment is sharpened by practice. P. salt is used in this way (an invention of Gahn); but is very inferior to P. acid, as the *complete* solution of any quantity of silica present in a mineral by the large amount of soda contained in a proportionate bead of P. salt before the blowpipe, is a mere question of heat or time. For instance, fine powder of the mineral *Cyanite*, which is half silica and half alumina, can be completely dissolved in a bead of P. salt by a hot gas lamp P.P. in a few minutes, and by a good O.P. of a mouth-blowpipe, in a quarter of an hour. (3) As hot glacial P. acid effervesces in blood-red bubbles *by itself*, with a trace of manganese, the use of nitre as a separate reagent for this purpose (advised in all books on Blowpipe Analysis) is obviated. I get my glacial phosphoric acid from Wooster, chemist, Turnham-green, W. (6d. per oz.). The sticks should be broken up into small fragments, each the size of a pea or large bead (I got a confectioner to cut mine up with his sugar-cutters), and kept in a wide-mouthed stoppered bottle for use. SODA AND POTASH (in reality dicarbonates of these metals) are indispensable as reagents. Potash must be kept in a small wide-mouthed stoppered bottle, on account of its deliquescence. Both are very cheap—half an ounce of each is an ample quantity to obtain—and the commercial soda (sodium carbonate) is generally pure; but I have purchased carbonate of potash from a respectable druggist in Notting Hill seriously adulterated, apparently with lime; it left a thick insoluble sediment in pure water. Test any residue from the solution of either in distilled water, in boric acid O.P. PURE LIME, for detecting traces of alumina with boric acid, as calcium borate; best kept as fragments of *clean* eggshells (washed with distilled water, but on no account with a solution of soda or alkali) which are to be calcined in O.P., supported in Pt. tongs (Figs. 32 or 33) and powdered on the agate slab immediately before use. PURE TUNGSTIC ACID, for detecting traces of phosphoric acid in minerals, &c. (sold as a yellow powder cheaply, in very small quantities, by analytical chemists). PURE TITANIC ACID, for detecting traces of boric acid in minerals, &c. (sold as yellowish white powder, cheaply, by chemists). Both of these can be kept in the penny corked bottles. COBALT NITRATE, sold cheaply in pink crystals. Some of these are to be dissolved in 10 parts of distilled water (by weight) and kept in the dropping bottle (Fig. 66) for use. The crystals should be carried or kept in a well-corked or stoppered bottle. POTASSIUM BISULPHATE (hydrogen, or "acid" potassium sulphate), 4½ parts used with 1 part powdered fluor-spar, for detecting boric acid. Sold cheaply by all scientific chemists in small bottles for this and other purposes. FLUOR SPAR, to be used as above described. POTASSIUM IODIDE and "FLOWERS OF SULPHUR," equal volumes of each, well mixed; used in Von Kobell's test for detecting bismuth. TEST PAPERS (should not be placed in contact).

1. Blue Litmus, for testing acids in salts, &c., by turning red when moistened and applied to them.

2. Red Litmus, for testing alkalies in salts, &c., by turning blue when moistened and applied to them.

3. Turmeric paper—yellow: turned reddish-brown by alkalies; a peculiar red by boric acid; and orange by zirconium solutions.

4. Brazil-wood paper—red: turned straw-yellow by fluorine.

MANGANESE SULPHATE, a cheap salt, in pink crystals, may also be kept for detection of baryta, &c. MAGNESIUM WIRE, sold in flat strips, by the inch, for detecting phosphoric acid. INDIGO SOLUTION, kept in a hollow glass prism, for detecting traces of potash in presence of soda in coloured flames.

OXIDE OF COPPER, for detecting chlorine by the azure-blue, compound pyrochrome afforded (a discovery by Gahn). See Table VI., 14—5.

If you fuse copper oxide with a metallic chloride on a B acid bead, even in O.P. it is *immediately reduced to metal* (copper) as long as the chlorine lasts; but if you similarly treat a sulphate, *green transparent balls* (cupric boro-sulphate) are formed in the bead.

GYPSUM, for detecting carbon. Heat the substance made into a paste with gypsum on Ag. foil (or a shilling) in O.P. If C is present, a *black or brown stain* will be left on adding water.

POTASSIUM PYROTUNGSTATE, made by fusing K carbonate with WO_3 in O.P. on Al plate, until all effervescence has ceased; for detecting phosphoric acid in minerals, &c.

SILVER FOIL (a clean shilling will do), for detecting sulphur in sulphates by the black stain the sulphurous substance gives it with a drop of water, after a *candle*—H.P. on C slip.

N.B.—All beads are best disengaged from the pt. wire, by holding them perpendicularly downwards in O.P. over the Al tray.

For the reactions of glacial phosphoric acid (which acts as a *dilute* acid when held in P.P.), see Table VI., column 6.

CHAPTER VIII.

FIRST OPERATIONS.—ALUMINIUM-PLATE REACTIONS OF METALS AND ALLOYS.

PYROLOGISTS can much more easily and cheaply make or procure specimens of pure—or approximately pure—metals than they can obtain pure oxides—as, for instance, by putting a strip of zinc in a vinegar solution of lead, in order to obtain pure lead; and I would, therefore, recommend the student to keep as nearly as possible a complete set of the former (except, of course, sodium, potassium, and such unkeepable and expensive metals, which, however useful elsewhere, are of little or no interest here) in the small glass bulbs, B, Fig. 29, which he will also require for analytical purposes. The cork must be lettered at top, or on the side, with the chemical symbol of the contained metal—as Zn for zinc; Zn + Pb for an alloy of equal parts of lead and zinc, &c.; and if the collector is "a neat-minded man" (as most pyrologists are), he will, doubtless, "fit up" an old seidlitz-powder case as a "cabinet," with shelves made by scissors, pasteboard, and gum, forming little "pigeonholes," in which the labelled cork of each bottle, wrapped in cotton wool and stuffed into the holes, is apparent. Any pure oxides he can afford to buy can be similarly labelled and kept (in rather larger tubes) as WO_3 for tungstic acid, &c. An "ink-eraser" takes out these labels when fresh ones have to be written. In the Tables (III. and VI.) he has an alphabetical list of the reactions of pure oxides, and also of combinations in boric acid and other reagents; and I have now the pleasure to insert here—the first ever given to students of Blowpipe Analysis—a "pictorial table," which can be consulted graphically or referentially, of the reactions of approximately pure metals, and some of their alloys, on naked aluminium plate, before the pyrocone of the hot-gas lamp, Fig. 21. These he had better go through carefully with his blowpipe and aluminium plate himself, if he wishes to have a thorough knowledge of the combined sublimates of the volatile metals and their alloys with which he will meet in after practice.

Before giving a description of these cuts, however, it will be necessary to enter into some detail as to the *rationale* of the aluminium plate reactions, and the best way of using the plate itself. The curious circumstances which led me, in 1871, to its discovery as a blowpipe support were detailed in a paper read before Section B of the British Association at York in 1881. I need not, therefore, refer to them here, further than to mention that the blowpipe experiments of 1871 led me then to conclude that there was reason to doubt the received opinion among chemists and metallurgists that the relative heat-conductivity of aluminium among metals is only 6, silver being first; or, "taking the mean conductivity of silver as 1,000, that of aluminium is only 665."* The under-mentioned writers, also, do not seem (or, at all events, I cannot obtain an account of their having seemed) to have detected the connection there undoubtedly is between heat-conductivity and the fusing point in metals. When I found in 1871 that my "aluminium plates" resisted the utmost heat of the blowpipe which I was able to bring to bear upon them, although aluminium was stated to have a low fusing point among metals, I could not help attributing the fact, perhaps erroneously, to its extraordinary power of *heat-conduction*, which is certainly far beyond that of silver (placed first in the Philosophical Transactions of the Royal Society), as thus expressed in my work, "Pyrology," 1875, p. 63.

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* Calvert and Johnson, *Phil. Trans.*, 1858, p. 349; also Wiedemann and Franz, *Pogg. Annal.*, LXXXIX. 497.

"Aluminium seems to possess the same immunity from pyrological injury which platinum has, for exactly opposite reasons. Platinum conducts heat so slowly and with such difficulty, that the *whole* of the piece of foil cannot be raised to the degree of heat necessary to insure the fusion of any point of it where the greatest heat is applied; while in the case of aluminium, the conduction of heat is so rapid through the whole mass, and from it to the pliers or holder (which should also be made of a good conducting metal, as iron), that, in like manner, communication to the *whole* fragment, of a degree of heat sufficient for the fusion of any one point, cannot be concentrated on that point." It may be objected to this hypothesis (Greek *'upo*, beneath, and *tithemi*, to place), that bismuth and tin, the conductivity of which (according to Calvert and Johnson, *loc. cit.*) is even feebler than that of platinum, have a lower fusing point than any other metal (Daniell and Person); but this seems to me rather a confirmation of the law, for it is readily imaginable that, if heat-conductivity is next to *nil* (Latin contraction of *nihil*, nothing) in a metal such as bismuth, fresh accessions of heat concentrated upon a single point, *must* either fuse it instantaneously, *or burn* it slowly away like charcoal.

But whatever be the cause of the non-fusion of aluminium before the blowpipe, there can be no possible doubt that the surprising results obtained from assays thus treated upon it, constituting its chief value as a blowpipe-support, although not yet quite perceived by some writers on the subject, are wholly due to its enormous powers of heat-conductivity. It seems odd, for instance, that Landauer, of Brunswick (or, rather, his translators), did not see this when they made the strange mistake of supposing that "the sublimate is thicker on aluminium than on charcoal, *because* the first-mentioned support does not become so strongly heated," &c.,[*] the fact being, that the part of a charcoal support where sublimates are deposited is positive ice in comparison with aluminium plate when in use, the whole of which becomes so hot as to severely burn the fingers of the incautious operator (see Fig. 25, *a*). The best plan, therefore, will be to give here a correct account of the supposed advantages of aluminium plate as a support for volatile assays over charcoal, or any other; with what I believe to be the *rationale* or reason of the same.

1. *Pure oxidation* of an assay can be perfectly carried out on the bare plate; whereas it is a simple impossibility on charcoal.

2. The blowpipe treatment upon it, of such metals as arsenic, antimony, &c., is perfectly harmless to aluminium; whereas it instantly ruins platinum or any other metal.

3. In subliming volatile metals B.B., the sublimates are partly blown away by the blast from the horizontal surface of charcoal; whereas they are completely caught

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[*] Die Beschläge setzen sich auf der Aluminium-platte in dickeren Schichten ab als auf Kohle, &c.—*Die Löthrohranalyse,* Zweite Auflage, Berlin, 1881, p. 28.

by, and deposited upon, the vertical surface of the aluminium plate, which is out of the blast-direction.

4. Charcoal being almost a non-conductor of heat, sublimates deposited upon its cold part are, when treated by O.P. or H.P., subjected to the whole heat of the pyrocone concentrated upon that spot, and, consequently, *all*, without distinction, volatilise; whereas the pyroconical heat is so rapidly conducted away from beneath sublimates deposited upon aluminium, that some (as arsenic) volatilise, whilst others (as antimony) remain; thus constituting an extremely valuable distinction, and, indeed, *separation* between the pyroxides of these metals.

5. It is very often necessary to scrape off some of the sublimate with a penknife, in order to subject it afterwards to the additional test of some reagent (as boric acid) B.B. This, which is a very simple matter with aluminium plate, the operator obtaining the pure pyroxide thereby, is almost an impossibility in the case of charcoal, as what little sublimate is left, is adulterated with charcoal-dust (containing silica, calcium-phosphate, &c.), which has a powerful reducing effect in after treatment.

6. Pyroxides or sublimates thus obtained upon aluminium (as, for instance, that of lead) can be easily made into "the best metallic paint," as they are deposited in the finest possible powder, and require no "grinding."

7. The fixed sublimates from volatile metals, which comprise the greater number, can be oxidised, "peroxidised," and "reduced," as often as the operator pleases, on aluminium plate, affording distinctive reactions every time; and, by alloying the metals with certain proportions of pure lead, and treating the alloy

in a charcoal "slip" (Fig. 26), sublimates may be easily obtained from the "fixed" metals, as gold, iron, cobalt, &c., and treated as above mentioned. All this is of course impossible with a charcoal support.

8. Many volatile metals, as the accompanying pictorial table shows, afford sublimates when treated *per se* B.B. on the bare plate, whilst others, before the mouth-blowpipe, will only yield a sublimate when treated on the C-slip (Fig. 25, B). It is evident that a valuable process of *separation* can be thus again effected, heretofore impossible. Constituent sublimates in *alloys* are evolved in the order of their volatility.

9. The pyrological use of aluminium plate has induced the discovery of a *black sublimate* from almost all these (volatile) metals, heretofore undiscerned on the black charcoal; whilst other fixed metals, as aluminium itself, produce *black fragments* when treated B.B. in boric acid. It is not easy to withstand the conviction, therefore, that old writers had some grounds for the names "semi or imperfect metals" they applied to these volatile substances, the black sublimates of which are *invariably* next the assay metal itself—torn from its very core as it were, by the point of the pyrocone—and, if oxides at all, are in the lowest state of oxidation.

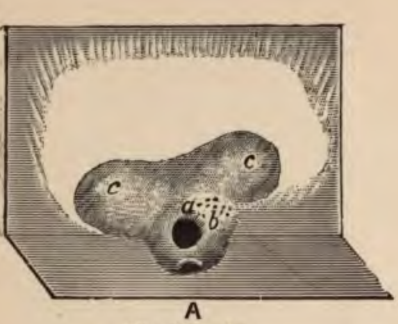
10. Soda and potash, &c., when treated B.B. on bare Al plate in small masses, *assume the spherical shape*, and are quite easily detached as a *ball* when the plate is cool, instead of lying in a little pool when fluid, and being scarcely at all detachable when cold, except by scraping with a penknife, as is the case with these reagents when fused B.B. on platinum. This is an immense advantage, enabling the operator to oxidise and reduce the reagent and its contents as though it

were a "bead" on pt. wire, and allowing him at once to dispense altogether with the use of the expensive "platinum spoon." The *rationale* I believe to lie in the fact that, from the rapid heat-conduction of the supporting aluminium, the *whole* mass above it is exposed to an equal amount of heat, and consequently is *all* equally fluid *at the same time*, so that all its particles or molecules are able to follow the great law of cohesion of liquids, by which the spherical form is assumed, as "that in which the mean distance of all parts from the centre of a mass is the least" (F. Guthrie, F.R.S.). In the slow-conducting platinum, on the contrary, the whole under part of the alkaline mass is comparatively cool, and the force of *adhesion* overcoming that of *cohesion*, the soda or potash is spread out as a little pool over that part of the platinum which had become red-hot.

Explanations of Cuts in Table IV.

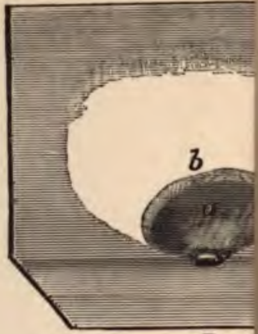
A. Sublimate of NATIVE ARSENIC.—*a*, black, shining, tar-like; *b*, grey, semi-metallic, with shining, minute, metallic balls, and iridescent streaks; *c c*, dull black, shading off to dark grey; remainder white. B. ZINC.—*a*, brown, with pale yellow border; *b*, white. B_2. ZINC SUBLIMATE AFTER LONG H.P.—*a*, brownish orange; *b b b*, lemon yellow border; *al*, *al*, *al*, spots of aluminium plate exposed by complete volatilisation of the sublimate; *c*, white, rounded by P.P. C. ALLOY OF ZINC AND LEAD.—*a*, black, thin; *b*, faint, iridescent. D. ANTIMONY.—*a*, mark of O.P. on white sublimate; *b*, the same after P.P.; *c'*, black sublimate; *d*, the same after P.P. E. ALLOY OF (A) + (D).—Strong garlic smell at first in O.P. No black sublimate above; As. quietly

Ta



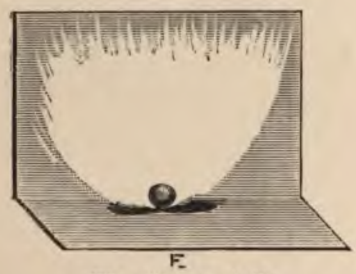
A

Fig. 98.—As



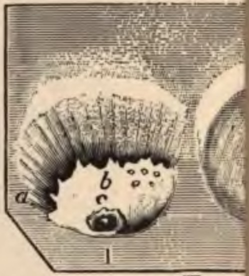
B

Fig. 99.—Z



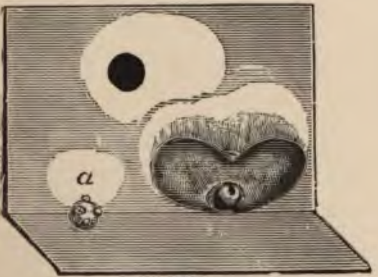
E

Fig. 103.—As + Sb



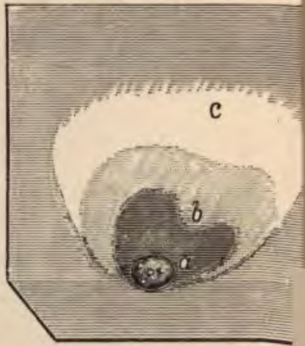
F

Fig. 104.—Pb   Pb a



K

Fig. 108.—Sb   +   Bi



L

Fig. 109.—Pb   +

N.B. Metallic F

volatilised in P.P. Remainder reacts in O.P., as in (D). F. 1. Lead.—Assay becomes red-hot with pale blue pyrochrome; not quite spherical, but shining and white, with a coat of litharge; *a*, coffee-brown; *b*, rich reddish brown; *c*, pale reddish cream-colour; next assay, grey, metallic, iridescent. 2. The same after P.P.; *a*, bright brick-red ("Red Lead"). The rest a dull brown, with faint white border. G. Alloy of (D) + (F.)—Part, black, dull; part, white. H. Bismuth.—*a*, metallic, black, iridescent; *b*, the same after O.P.; *c*, faint dirty yellow, with minute metallic balls. J. Bismuth on C.-Slip.—Assay glows brilliantly red-hot; *a*, rich brown yellow; *b*, lemon-yellow, shading off to white; over this, a thin halo of orange. *Above in P.P., d d d*, a rich coffee-brown shading off to (*a*) brown-yellow. K. Alloy of (D) + (H).—Assay covered with small shining balls by slight O.P.; (Bi) *a*, faint semi-metallic white sublimate; after strong O.P. assay grey, metallic, with small shining ball on top; black, pansy-shaped sublimate, grey towards assay, with thin white sublimate; through lens yellow on surface. After slight P.P. orange and green hot; pale yellow and white cold; *a*, black spot after O.P., showing Sb. L. Alloy of (F) + (H).—Assay bright red-hot; not round; and coated with litharge. Many minute balls on surface, which seem to move out, like snails' "horns," while red-hot (Bi).

a. Grey, semi-metallic with black border.

b. Blackish brown, pansy-shaped, with coffee-brown border.

c. Yellowish or dirty white. *Above after P.P.*

b. Blackish and coffee-brown; *c*, yellowish or brownish white. *Above in H.P.*, a rich velvet black, which turned slowly in P.P. to a dirty blackish brown; and

Table V.—Reactions of Volatile Metals on Aluminium Plate with Charcoal-Slip, O.P.

Metal.	Sublimates.	Subt. after O. P.	Subt. after H. P.	Subt. after P. P.	Remarks.
Antimony	1. Black. 2. Pale yellow. 3. White. 4. Bluish white.	A black round spot.†	A black round spot.	1. Unaltered. 2. ,, 3. Brighter yellow, hot.	Subt. of sulphide, dark yellow and yellowish red; slowly oxidising in P. P. to normal colours.
,, + Lead...	1. Large black subt. 2. Copious white subt.	1. Unaltered. 2. Round black spot (Sb).	1. Unaltered. 2. Round black spot (Sb).	1. Grey. 2. Pale yellow, hot (Sb).	Only Sb subt. afforded here. It may therefore, be thus entirely separated from its alloy with lead.
Arsenic	1. Black, shining, tar-like. 2. White, with bluish border.	Rapidly vol. in round spot.†	Rapidly vol. in round spot.	Imperceptibly volatilised.	Separated from Sb by gently heating the alloy on the bare plate O.P., and treating the subt. as formed, with long P.P. Smell of garlic.
Bismuth	1. Copious yellow and on ledge. 2. Orange. 3. Brown. 4. Pale yellow.	Coffee-brown.	Brown black.	Darkens temporarily.†	A tri-alloy of Sb, Pb, and Bi, may be depurated in the above order by covering the assay with H.P. on face of plate. Sb subt. is first obtained, then Pb, and Bi is left behind.
Cadmium	1. Reddish brown. 2. Blackish brown.	Slowly vol.	Slowly vol.	Unaltered.	More volatile than zinc, and thus separated from it.†
Gold	1. Pale yellow (metc.) 2. Purplish violet.	Unaltered.	Unaltered.	Renews the violet colour when it has become brown by standing for some days.	These colours can be much more easily and copiously produced by adding 1 per cent. of pure lead to the assay, when Au is detected (by P. acid O.P.) in the pure white subt.
Lead	1. Lemon yellow. 2. Orange, or brick-red. 3. Coffee brown. 4. White.	Blackish brown.	Brownish black.	Coffee-brown.†	More volatile than Bi. Can be removed from a Bi alloy by a strong H.P. covering the assay on the bare plate.†

Molybdenum ...	1. Pale yellow. 2. White.	A bluish round spot; green is impure, as in Wulfenite.	Dark blue spot, like a peacock's "tail-eye."† Green, if impure.	Yellow while hot.	More volatile than Pb, from which it can be separated therefore, by O.P. on the bare plate.†
Selenium.........	1. Brownish velvet-black. 2. White subt. 3. Copper metc.-like subt.	1. Instantly black. 2. " " 3. Bronze colour.	Black-brown.	White.	Strong smell of rotten horse-radish in H.P. Can be separated from Pb by O.P. on the bare plate.†
Silver	Faint gold-yellow semi-metc. subt. Myriads of gold-yellow balls (thro' lens).	Balls scattered two inches apart.	Round spot, like "frosted silver."	Balls scattered over the plate.	With Pb and Sb a magnificent purple violet subt., turning brown from exposure of some hours, and cannot be restored by O.P. like the subt. of Au + Pb.†
Tellurium	1. Greyish black. 2. Brown. 3. White.	1. Brownish yellow. 2. Pale drab. 3. " "	Black.	White.	Can be volatilised on the bare plate by O.P. from most metals, except Se or As.†
Thallium	1. White. 2. Reddish brown.	Blackish brown.	Black.	1. Reddish brown. 2. White.	A bright green p.c.†
Tin	Assay covered with a thick crust of SnO_2. No subt. on plate.†	Crust unaltered.	Crust partly reduced to metal; part falls off in thick white flakes.	Crust unaltered.	Sn *sweats* by slight O.P. from alloys like Bi (Figs. 108, 109).† Can be easily separated from Pb and other alloys by H.P. in which Sn affords no subt., while all other volatile metals thus sublime.
Zinc	1. Black subt. 2. White subt.	1. White, bright yellow hot. 2. Edge slowly vol. and rounded.†	Slowly but clearly volatilised to a clear round spot.†	Bright canary yellow hot; white again cold.†	Traces of some volatile alloys can be removed from Zn by keeping the assay covered with a good H.P., when Zn does not so readily sublime as most others.

N.B.—1 = nearest the assay; 2, next above 1; and so on. † A very distinctive reaction.

this would not turn black again in H.P., showing that the black colour is not due to carbon from the pyrocone. M. PURE SILVER (*reduced from the nitrate*).—*a*, *a*, Faint, reddish, gold-like yellow metallic halo, showing through a lens myriads of minute gold-yellow metallic balls, scattered by a strong P.P. two inches. Assay covered with a thick coating of oxide, like horn. On C-slip a similar result without the oxide. N. Ag + Pb *a*, Pale, bluish-green iridescent halo. *b*, Pinkish, dirty brown; millions of metallic balls over *a* and *b*, O. Ag + Sb *a*, Deep velvet-black pansy-shaped halo, which falls off in flakes when cold, shading off to metallic grey, towards the dark grey assay ball. *b*, Faint yellowish white. The rest white, thick. This table should be hand-coloured by the student, according to the directions above given.

The slightest trace of alloy of *lead* with *tin* may be detected in a few minutes on Al plates, by keeping the assay ("block tin" for instance) on a C-slip, enveloped in a good H.P. The tin will not oxidise as long as it is covered by H.P., whilst all lead is thus rapidly deposited on the vertical plate-surface as a white sublimate which *turns brown* after P.P. The moment H.P. is removed from the red-hot assay, it is covered with a thick crust of tin dioxide, and cools snow-white, which may be reduced to metal by adding a little borax, and covering the mass with a good blue H.P.

If any alloy ball (as of gold with silver) be placed on bare aluminium plate, and gently heated on one side for some time with P.P., the metal possessing the lowest fusing point will imperceptibly melt, and its molecules *gradually flow towards the source of heat*, remaining eventually on that side. The Alloy (Au + Ag) will be found

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white on that side, and yellow on the other. A kind of "parting" is thus effected. The alloy must *not* be raised to the fusing point, but kept red-hot.

The Table opposite (VI.) should be now studied by first learning carefully the reactions of oxides, &c., in the *lines* from 1 to 61; then those afforded by supports and reagents in the *columns* 2 to 7.

The more familiar the student is with these in the first place, the more competent will he be to proceed with the analysis of difficult minerals.

CHAPTER IX.

ON PYROLOGICAL MINERALOGY, AND A PROPOSED SPECIFIC GRAVITOMETER, ETC.

MINERALOGICAL SCIENCE may be (conscientiously) divided into two parts, which are almost separate from each other. Part I. treats of the geometric and optical properties of the beautiful and symmetrical crystalline forms (Greek *krystallos,* a crystal) we so often behold in underground nature—that is in collections of crystalline minerals brought from mines, &c.; and Londoners have special facilities for examining these, as the splendid British-Museum collection at South Kensington, under the clever and courteous superintendence of Mr. Lazarus Fletcher, is, I believe, the finest and most complete in the world; that of Vienna coming next. But "geometric and optical properties of crystals" comprise two of the most difficult portions of the higher mathematics, and can only, therefore, be *properly* studied by an able mathematician; so that the study, however interesting, can have no place here, although the simple measurement of crystalline angles may certainly be (and shall be here) employed. The determined student, however, may be referred to the "Mineralogy" of the late Prof. W. H. Miller, of Cambridge, the first of English mineralogists (Longman and Co., 1852), modestly but absurdly called by him "Phillips's Mineralogy;" to the capital but too brief work of

Prof. Nicol, of Aberdeen; and, not least, to the splendid American "System of Mineralogy" by Prof. J. D. Dana, 1877.

Part II. relates to what has been called "Determinative Mineralogy;" a title which, as the word "determination" in analysis is properly applied to *quantitative* results, I have ventured to alter here to "Pyrological Mineralogy." It facilitates the identification of Minerals and "Rocks," so that each may be relegated (Latin *relego,* I transfer) to its proper place in the "system" arranged for it, crystallo-graphically or otherwise, by Part I.; and this work is, nowadays, almost universally carried out by means of the Blowpipe. By adopting this system of Blowpipe Analysis, the student will soon see that he can perform it by means of the blowpipe *alone*: in every other system, as is well known, frequent application must be made to the violent fluid acids—nitric, hydrochloric, or sulphuric (sometimes to all three), which, as is also well known, are almost impossible to carry without the greatest risk of serious injury. Without further preface, I now beg to introduce to the student the following tables, which explain (or ought to explain) themselves, and he will have to study them carefully, especially VII. and IX., before beginning Chapter X., in which we commence our *Actual Work.*

The next Table (VII.) will be found useful in guiding the analyst to the proper treatment of the substance he is going to examine. It requires no explanation, but the neglect of employing its assistance in the first place, will probably entail a loss of both time and patience.

Table VII.—General Guide to First Analytical Operations.

a. First behaviour of powder in Boric acid O.P.	b. Lustre.	c. Sp. Gr.	d. Hardness.	e. Streak.	f. Transmitted light.	g. Smell in first O.P. or H.P.	h. Next treatment.
1. O	Metallic	Over 5	Under 5	Shining, &c.	Opaque	Various	Fragment or paste on bare Al plate O.P., then on C slip H.P., then with soda H.P.
2. O	Vitreous to earthy, &c.	Generally under 5	Generally over 5	White or coloured earthy	Transparent to opaque	O	Powder in Boric acid O.P. (See Tables III. and VI., col. 4.)
3. Effervesces and fumes ... (See page 45, Fig. 45.)	Vitreous to earthy, &c.	Under 5	Under 5	White or earthy	Transparent to opaque	Garlic, or of ignited lucifer matches.	Paste on Al plate O.P. for arsenic or antimonic acid.
4. Effervesces and smokes or fumes	Vitreous to earthy, &c.	Under 5	Under 5	White or earthy, &c.	Transparent to opaque	Suffocating, like chlorine	1. Add copper oxide to the bead O.P. (for chlorine). 2. Powder with P acid and water in glass bulb (for fluorine). 3. If effervescence without smell, test for sulphuric or carbonic acid.
5. Fuses instantly at bottom of bead, forming insoluble fragments afterwards	Vitreous to earthy, &c.	Generally under 5	Generally under 5	White or earthy, &c.	Transparent to opaque	O	1. Note the pyrochrome of powder, and test with tungstic for phosphoric acid, or with Ti acid for Boric acid. 2. Note the pyrochrome of fragment in H.P. for P acid, or with $KHSO_4$ and fluor-spar for boric acid.
6. Fuses at bottom of bead, forming a jelly afterwards	Vitreous to earthy, &c.	Under or over 5	Under or over 5	White or earthy, &c.	Transparent to opaque	O	Fuse the powder (with soda if necessary) on the bare Al plate O.P.; boil the mass, and treat the dried residue in phosphoboric acid* O.P., for silica, alumina, and other oxides not alkaline,
7. An opaque, milk-white, enamel-like bead	Vitreous to earthy, &c.	Under or over 5	Under or over 5	White or earthy, &c.	Transparent to opaque	O	Proceed as above, but test specially in the bead for alumina (with or without silica) *and* lime.
8. Insoluble opaque white fragments	Vitreous to earthy, &c.	Under or over 5	Under or over 5	White or earthy, &c.	Transparent to opaque	O	Add calcined lime powder O.P. to test specially for alumina or glucina, then in P acid P.P. for silica or zirconia.

* Made by dipping the red-hot Boric-acid bead into pure, deliquesced phosphoric acid.

Table VIII.—Fractions and Percentages.

(For approximating* quantitative reactions.)

Per cent.		Total composition.
8	equal to about	1-12th
9	,,	1-11th
10	,,	1-10th
11	,,	1-9th
12	,,	1-8th
14	,,	1-7th
17	,,	1-6th
20	,,	1-5th
25	,,	1-4th
28	,,	2-7ths
33	,,	1-3rd
36	,,	3-8ths
40	,,	2-5ths
42	,,	3-7ths
44	equal to about	4-9ths
45	,,	5-11ths
50	,,	1-2nd
54	,,	6-11ths
56	,,	4-7ths
60	,,	3-5ths
66	,,	2-3rds
70	,,	5-7ths
75	,,	3-4ths
80	,,	4-5ths
84	,,	6-7ths
85	,,	5-6ths
90	,,	9-10ths

		Per cent.
1-2nd	about	50
1-3rd	,,	33
1-4th	,,	25
1-5th	,,	20
1-6th	,,	17
1-7th	,,	14
1-8th	,,	12
1-9th	,,	11
1-10th	,,	10
1-11th	,,	9
1-12th	,,	8
2-3rds	,,	66
2-4ths	,,	75
2-5ths	,,	40
3-5ths	,,	60
4-5ths	,,	80
5-6ths	,,	85
2-7ths	,,	28
3-7ths	,,	42
4-7ths	,,	56
5-7ths	,,	70
6-7ths	,,	84
3-8ths	,,	36
5-8ths	,,	60
7-8ths	about	84
2-9ths	,,	22
4-9ths	,,	44
5-9ths	,,	44
7-9ths	,,	77
8-9ths	,,	88
3-10ths	,,	30
7-10ths	,,	70
9-10ths	,,	90
2-11ths	,,	18
3-11ths	,,	27
4-11ths	,,	36
5-11ths	,,	45
6-11ths	,,	54
7-11ths	,,	63
8-11ths	,,	72
9-11ths	,,	81
10-11ths	,,	90
5-12ths	,,	45
7-12ths	,,	56
9-12ths	,,	72
11-12ths	,,	88
1-14th	,,	7

* Latin *ad*, to, and *proximus*, nearest.

Table IX.—Of Assay Squares. (Fig. 113.)

(For approximating quantitative reactions.)

In order to use this table (see also the previous one), the student should cover square (2) with a thin slice of unclouded agate, or, if that cannot be obtained, with a piece of glass. He should then cover the square (seen through the transparent medium) with the fine powder

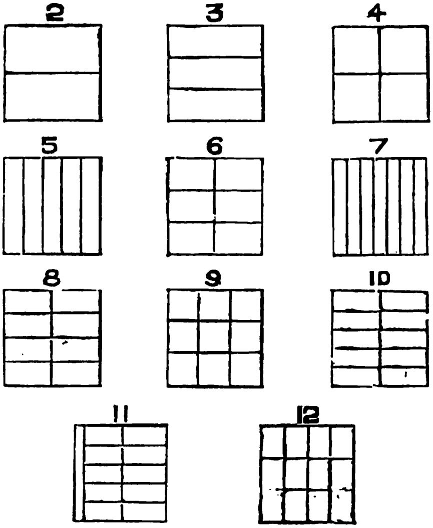

Fig. 113.

of any pure oxide, say silica, and pack it down with a fine steel spatula (a piece of flat watch-spring answers admirably), so that all inner lines are *just* not visible, but there should be no greater depth of powder than this. He then takes up the whole of the powder by degrees, with a hot bead of boric acid on pt. wire, and, after treating with O.P. and flattening the hot bead by firmly pressing it on an aluminium plate with the fore-finger in a platinum capsule lined with moist chamois leather, he observes through a lens how large this quantity thus appears in the flat bead. He should then try another oxide, say alumina, in the same way, and observe the difference in appearance of several fractional parts of the square of powder. After going through as many as he can of the pure oxides in this manner, he should place the flattened transparent bead over the square corresponding to the supposed character of the mineral to be analyzed; minerals with few constituents correspond to squares with few divisions, *e.g.* (Latin *exempli gratia,* for example), suppose the mineral to be analyzed, be thoroughly-roasted "rich" *Smaltite.* The operator observes that black opaque balls which turn violet after H.P., represent a part of the original powder which would have covered one of the spaces of square (6): he thus knows that about one-sixth of this mineral consists of *cobalt.* In like manner he finds an amount of green fragments, which assume a white metallic lustre after H.P. representing a portion of the powder, which would have only filled one of the spaces of square (8), and considers about one-eighth of this mineral to be *nickel.* Again he finds so few brown-black opaque balls present, that the proportion of powder they represent would not have even half covered one of the spaces of square (12), and so enters "very little iron" in his notes. Opacity in the bead is remedied by boiling, &c., as directed at page 84. All proportions below one-twelfth are to be entered as "little;" all below one-thirty-third (or about 3 per cent.) as "very little;" all below 1·0 per cent. as "a trace."

A Proposed Specific Gravitometer.

"Every schoolboy" knows the story of how Archimedes discovered the fraud of brass in King Hiero's "golden" crown, by the deficient specific gravity of the alloy, through the proportional displacement of water; but few mineralogists seem to have considered if the modern expensive and elaborate modification of this method (weighing the substance hanging at the bottom of an assay-balance pan in water) may not be again modified by a more simple, cheap, and portable, if less mathematically correct instrument, for the benefit of travellers, and thousands of others, to whom "an assay-balance" is all but an impossibility, and who, therefore, often, nowadays, "solve" this important question by "carefully" poising the substance in the right hand!

The accompanying drawings and references will perhaps be sufficient for purposes of explanation; but the way to determine the gradations of the scale on tube *d* is by first noting (with a file on the tube) the quantity of water displaced by the fall of the empty box *a*; then filling it with pure platinum filings, and marking *this* displacement of water as 22, commencing from the notch above made; because 22 is the specific gravity of pure platinum ("Deschanel," p. 86). The maker then similarly drops the box *a* filled with pure gold filings, and marks the point of its displacement 19·6, because this is the specific gravity of pure gold. The space between these two last points is, of course, to be graduated 2·4 "degrees;" and this will give the dimensions of the *degrees* for the rest of the tube upwards. The length

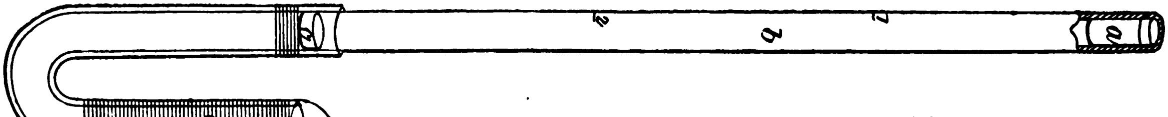

Fig. 114.

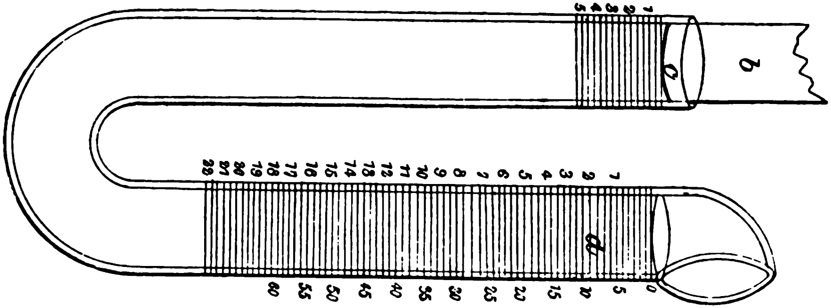

Fig. 115.

References to Figs. 114 and 115. (Scale of Fig. 114—1·5 in. to the foot.)

a, a small brass box filled with the fine sand of the substance, the specific gravity of which is to be determined. The outer diameter of this box must be as near as possible to the inner diameter of the tube *b*, but the box must pass down the latter without obstruction.

b, a brass or copper tube, supposed to require to be about 3 ft. long, down which, standing perpendicularly, the box *a* filled with the mineral sand is to be dropped.

c, a little oil covered by a pasteboard or wooden disc or wad, to receive the first impact of the sand-laden box *a*.

d, a strong **U**-bent glass tube, filled with rain or distilled water, covered in its left leg with oil (*c*), and graduated outside its right leg with a scale (determined by the box *a*, full of platinum filings or sand), showing the amount of water displaced by the fall of the box (*a*). The right leg is covered by the slightly bent tube to prevent any water spirting up and dropping back into the tube.

The left leg of the tube may be graduated at *c* in order to measure the first energy of impact.

of the box *a* is determined by the convenience to the maker of the point 22. If he requires 22 to be *very* low down on the tube, *a* must be a long box, and *vice versâ.* Of course, if necessary, the box can be withdrawn by a silk thread attached to the top.

It may be objected that this method does not show the actual displacement of water, inasmuch as the substance does not take the place of the water—*i.e.* is not actually immersed in it; but that does not matter to the operator, as long as the correctness of his scale of specific weights is certified (as it, of course, will be here) by two *standards* of pure substances—platinum and gold—and the displacement points of these two ought not to be marked except as the result of many careful experiments.

Table X.—The Paragenesis[*] of some Ores.

(Compiled from Von Cotta's "Lehre von den Erzlagerstätten.")

Cassiterite (Kassiter'ite) is often associated with 1, Quartz; 2, Schorl; 3, Chlorite (Klo'rite); 4, Mispickel; 5, Pyrite; 6, Blende.

Chalcopyrite (Kalkopy'rite) is often associated with 1, Quartz; 2. Fluor-spar; 3, Galena; 4, Blende; 5, Chalybite (Kaly'bite); 6. Dolomite; 7. Pyrite.

Cuprite (Kup'rite) is often associated with 1, Quartz; 2, Native Copper; 3, Malachite; 4, Chessylite (ch soft, as in "cheese").

Fluor-spar is often associated with 1, Quartz; 2, Wolframite; 3, Chlorite; 4, Orthoclase; 5, Chalybite; 6, Chalcopyrite.

Galena is often associated with 1, Quartz; 2, Pyrite; 3, Chalcopyrite; 4, Blende.

Gold is often associated with 1, Quartz; 2, Tellurium; 3, Pyrite.

Pyrite is often associated with 1, Quartz; 2, Cassiterite; 3, Chalcopyrite; 4, Galena; 5, Fluor-spar; 6, Mispickel; 7, Limonite.

Quartz is often associated with 1, Orthoclase; 2, Mica; 3, Schorl; 4, Chlorite; 5, Chalybite; 6, Calcite; 7, Dolomite; 8, Baryta; 9, Fluor-spar; 10, Cassiterite; 11, Pyrite; 12, Chalcopyrite; 13, Limonite; 14, Wolframite; 15, Cuprite; 16, Galena; 17, Blende; 18, Bournonite; 19, Native Gold; 20, Native Copper.

Serpentine is often associated with 1, Steatite; 2, Diallage; 3, Asbestus; 4, Copper; 5, Chrysocolla.

N.B.—The numbers, of course, refer to the frequency of association, 1 being most frequent.

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[*] Greek *para*, near, and *genesis*, formation.

Table XI.—Geological Subformations with the containing Systems.

(Compiled chiefly from Lyell and Penning.)

	SUBFORMATION.	SYSTEM.
1.	Alum schists of Sweden and Norway	Cambrian (upper)
2.	Albien	Cretaceous (up. div.)
3.	Ashdown sand: Wealden	Ditto
4.	Ancient Nile-mud forming river terraces	Pleistocene
5.	Argile de Londres (near Dunkirk)	Eocene (lower)
6.	Argile plastique	Ditto
7.	Aptien	Cretaceous
8.	Aymestry beds	Silurian
9.	Bala beds	Ditto (lower)
10.	Basin (Mayence and Vienna)	Miocene (lower & up.)
11.	Do. (Paris)	Eocene (upper)
12.	Bembridge series	Eocene
13.	Bagshot and Bracklesham beds	Ditto
14.	Bath Oolite	Jurassic
15.	Blackdown beds	Cretaceous (upper)
16.	Bolderberg beds of Belgium	Miocene (upper)
17.	Bone bed	Silurian (upper)
18.	Bovey Tracey plant beds	Miocene
19.	Breccias, Australian Cave	Pleistocene
20.	Do. Penrith and Dumfriesshire	Permian
21.	Bunter sandstone of Lancashire and Cheshire	Trias (middle)
22.	Do. of Germany	Ditto (lower)
23.	Bridlington Beds, Marine Arctic fauna	Pliocene (newer)
24.	Caradoc beds	Silurian (lower)
25.	Calcaire grossier	Eocene (middle)
26.	Do. silicieux	Ditto (upper)
27.	Claiborne beds of United States	Ditto (middle)
28.	Chalk Marl	Cretaceous
29.	Do. Maestricht	Ditto
30.	Do. (mid.) (low) (up. with flints)	Ditto
31.	Do. Faxoe	Ditto (upper)
32.	Calcareous Sicilian strata	Pliocene (newer)
33.	Clay Atherfield	Cretaceous
34.	Do. Alum Bay and Bournemouth	Eocene (upper)
35.	Do. Aix-la-Chapelle	Cretaceous (upper)
36.	Do. Barton	Eocene
37.	Do. Bovey Tracey	Miocene (upper)
38.	Do. Bradford	Jurassic
39.	Do. Kimmeridge	Oolite (upper)
40.	Do. London	Eocene (middle)
41.	Do. Lower Gault	Cretaceous
42.	Do. Oxford	Jurassic (m. oolite)

	SUBFORMATION.	SYSTEM.
43.	Clay Speeton, of Flamboro' Head	Cretaceous (lower)
44.	Do. Weald of Surrey, Kent, and Sussex	Ditto
45.	Chillesford beds, chiefly Arctic	Pliocene (newer)
46.	Coalfield of Richmond, Virginia	Trias (upper)
47.	Do. North Carolina	Ditto
48.	Do. South Wales with underclays	Carboniferous (upper)
49.	Do. North and Central England	Ditto
50.	Do. Kilkenny, Ireland	Ditto
51.	Do. Saarbruck	Ditto
52.	Do. Pennsylvania	Ditto
53.	Do. strata of South Joggins, Nova Scotia	Ditto
54.	Do. slate of Ireland	Ditto (lower)
55.	Do. limestones and sandstones of Scotland	Ditto
56.	Conglomerate of North Germany	Cretaceous (lower)
57.	Do. Dolomitic of Bristol	Trias (upper)
58.	Coral rag	Jurassic
58A.	Corallien	Ditto
59.	Coralline crag	Pliocene (older)
60.	Cornbrash	Oolite (middle)
61.	Cypridinen — Schiefer and Clymenienkalk, Rhenish provinces	Devonian (upper)
62.	Douriton sandstone or bone bed	Silurian
63.	Danian or Maestricht chalk	Cretaceous
64.	Dordogne caves of Reindeer period	Pleistocene
65.	Drift, Salisbury, with bones of Mammoth, &c.	Recent
66.	Dolomitic limestone	Permian
67.	Devonian rocks—lower, middle, and upper	Devonian
68.	Erratics of Pagham and Selsea Bill	Recent (Post Tert.)
69.	Earth, Fuller's, of Bath	Oolite (lower)
70.	Flags, Arenig	Cambrian
71.	Do. Lingula	Ditto
72.	Do. Llandeilo	Ditto
73.	Faluns of Touraine	Miocene (upper)
74.	Do. Bordeaux	Ditto
75.	Freshwater strata of Germany (France, bones of *Pliopithecus*)	Ditto
76.	Faxoe chalk	Cretaceous (upper)
77.	Gault (lower and upper)	Cretaceous
78.	Greensand upper ("Firestone" of Surrey)	Ditto
79.	Gannister beds	Carboniferous
80.	Gypsum of Montmartre	Eocene (upper)
81.	Grès de Beauchamp	Ditto
82.	Grit Obolus (of Russia)	Silurian (lower)
83.	Do. Millstone	Carboniferous
84.	Do. Harlech	Cambrian (upper)
85.	Gneiss fundamental of the Hebrides?	Ditto (lower)
86.	Do. and Quartzite containing *Eozoon Canadense*	Laurentian (lower)
87.	Harlech beds	Cambrian

	SUBFORMATION.	SYSTEM.
88.	Headon beds	Eocene
89.	Hempstead beds	Miocene (lower)
90.	Hallstadt beds (marine fauna, N.W. Germany)	Trias (upper)
91.	Huronian Series (Canada)	Cambrian (lower)
92.	Ilfracombe beds	Devonian (upper)
93.	Kleynspawen beds (Belgium)	Miocene (lower)
94.	Kelloway rock	Jurassic
95.	Keuper sandstone	Ditto
96.	Do. beds of Germany	Trias (upper)
97.	Küpfer schiefer	Permian
98.	Kalk Pläner (Saxony)	Cretaceous (upper)
99.	Lacustrine beds of Auvergne	Miocene
100.	Do. mud (Swiss lake dwellings)	Recent
101.	Do. strata of Upper Val d'Arno (Italy)	Pliocene (newer)
102.	Loess of the Rhine	Pleistocene
103.	Loam and Breccia of Liège caverns	Ditto
104.	Leaf bed and land shells of Madeira	Pliocene (newer)
105.	Limestone, Aymestry	Silurian
106.	Do. mountain (sub-carbon)	Carboniferous
107.	Do. hippurite	Cretaceous (upper)
108.	Do. magnesian (Zechstein)	Permian
109.	Do. Wenlock	Silurian
110.	Do. and volcanic tuff of Madeira	Miocene (upper)
111.	Do. Miliolitic of France	Eocene (middle)
112.	Do. Nerinœan of the Jura	Oolite (middle)
113.	Do. Torquay (with numerous corals)	Devonian (upper)
114.	Do. Eifel (with underlying schists, Germany)	Ditto
115.	Do. with sandstones of Russia	Ditto
116.	Do. Woolhope	Ditto (lower)
117.	Do. Niagara	Silurian (upper)
118.	Do. Trenton (N. America)	Ditto (lower)
119.	Do. Pisoltic of France	Cretaceous
120.	Llandovery beds (lower)	Cambrian
121.	Do. (upper)	Silurian
122.	Lias (lower and upper)	Jurassic
123.	Ludlow beds	Silurian (upper)
124.	Lignites and clays of Bovey Tracey (Devonshire)	Miocene (lower)
125.	Do. beds of Cadibona (Italy)	Ditto
126.	Marine strata of Puzzuoli (Temple of Serapis)	Recent
127.	Magnesian limestone of Russia, &c.	Permian
128.	Marble (forest)	Jurassic
129.	Marls (sub-apennine)	Pliocene (older)
130.	Do. (Keuper)	Triassic
131.	Do. slate	Permian
132.	Do. chalk	Cretaceous
133.	Marlstone	Jurassic
134.	Mayhill sandstone	Silurian

	SUBFORMATION.	SYSTEM.
135.	Mudstones	Silurian
136.	Millstone grit	Carboniferous (upper)
137.	Menevian beds	Cambrian
138.	Muschelkalk	Triassic
139.	Molasse (Marine, of Switzerland)	Miocene (upper)
140.	Marine strata of the Atlantic border, U.S.	Ditto
141.	Mayence basin	Ditto (low. & up.)
142.	Maestricht beds	Cretaceous (upper)
143.	Marnes à gryphées	Oolite (upper)
144.	Marl slate of Durham and Yorkshire	Permian
145.	Mergel (or Küpfer) scheifer	Ditto
146.	Nebraska beds, U.S.	Miocene (lower)
147.	Neocomian of Neufchatel, &c.	Cretaceous (lower)
148.	Nummulitic formation of Europe, Asia, &c.	Eocene (lower)
148A.	Norwich crag	Pliocene
149.	Nerinœan limestone of the Jura (oolitic)	Jurassic
150.	Old red sandstone (lower, middle, upper)	Devonian
151.	Oolite (lower, middle, upper)	Jurassic
152.	Osborne series	Eocene (upper)
153.	Œnninghen beds (Switzerland)	Miocene (upper
154.	Portland beds	Jurassic
155.	Purbeck beds (lower, middle, upper)	Ditto
156.	Paris basin	Eocene (upper)
157.	Punfield marine beds	Cretaceous (lower)
158.	Pikermi deposit (Athens)	Miocene (upper)
159.	Red crag of Suffolk	Pliocene (older)
160.	Rupelmonde beds (of Belgium)	Miocene (lower)
161.	Radaboj beds (Croatia)	Ditto
162.	Reading series, or Woolwich beds, or Thanet Sands	Eocene (lower)
163.	Rag, coral, of Berks, Wilts, and Yorkshire	Jurassic
164.	Rhœtic beds (Bavarian Alps)	Triassic
165.	Rock, Kelloway, of Wilts and Yorkshire	Jurassic
166.	Roth Liegendes (Thuringia)	Permian
167.	Rocks, hypersthene, of Skye	Laurentian (upper)
168.	Sandstone, new red (Bunter, Germany, Lancashire and Cheshire)	Triassic
169.	Do. Mayhill	Silurian (upper)
170.	Do. old red	Devonian
171.	Do. Rothliegende (lower, upper)	Permian
172.	Do. Douriton	Silurian (upper)
173.	Sands, Thanet	Eocene (lower)
174.	Do. Bagshot	Eocene
175.	Slate (lower) limestone	Carboniferous
176.	Do. Marl (Küpfer schiefer)	Permian
177.	Shale, Wenlock	Silurian (upper)
178.	Do. Woolhope	Ditto
179.	Do. limestone (lower)	Carboniferous
180.	Slates Skiddaw	Cambrian

	SUBFORMATION.	SYSTEM.
181.	Slates, Tremadoc	Cambrian
182.	Senonien	Cretaceous
183.	Sub-apennine marls and sands	Pliocene (older)
184.	Superga beds (near Turin)	Miocene (upper)
185.	Siwalik strata (India)	Ditto
186.	Speeton clay of Flamborough Head	Cretaceous (lower)
187.	Saarbruck coalfield	Carboniferous (upper)
188.	St. Helen's (Osborne) series	Eocene (upper)
189.	Sable Moyen (sands and marls, Paris basin)	Ditto
190.	Soissonnais sands	Miocene (middle)
191.	Sable de Fracheux	Eocene (lower)
192.	Sands and clays of Aix-la-Chapelle	Cretaceous (upper)
193.	Do. of Folkstone, Sandgate, Hythe, and I. of Wight	Ditto (lower)
194.	Do. Tealby	Ditto
195.	Do. Hastings	Ditto
196.	Do. Portland	Jurassic
197.	Do. Ashdown (Wealden)	Cretaceous
198.	Do. sub-apennine	Pliocene (older)
199.	Sandstone of Penrith and Dumfries	Permian (lower)
200.	Do. of Connecticut (footprints of birds, &c.)	Trias (lower)
201.	Do. of Dura Dean (Fifeshire)	Devonian (upper)
202.	Do. of Forfarshire and Perthshire	Ditto
203.	Do. Pilton of N. Devon	Ditto
204.	Do. Petherwyn, Cornwall	Ditto
205.	Do. of Russia	Ditto (middle)
206.	Do. (lower) of Forfarshire	Ditto (lower)
207.	Do. of Western Canada and New York (Oriskang)	Ditto
208.	Do. of Gaspé, Eastern Canada	Ditto
209.	Do. Downton	Silurian (upper)
210.	Do. Potsdam, Canada, and U.S.	Cambrian (upper)
211.	Do. Fucoidal, of Sweden	Ditto (lower)
212.	Stone, Portland	Jurassic
213.	Do. lithographic of Solenhofen	Ditto
214.	Slate, Stonesfield	Ditto
215.	Do. Llanberis	Cambrian (lower)
216.	Shales, red, of Cheshire and Lancashire, with rock salt	Trias (upper)
217.	Schists, bituminous, of Gamrie, Caithness, &c.	Devonian (middle)
218.	Do. Eifel (Germany, calceola-schiefer)	Ditto
219.	Stones, paving (Arbroath)	Ditto (lower)
220.	Shales, Tarannon (Wales)	Silurian (upper)
221.	Slates (lower) Llandovery	Ditto
222.	Schists, alum, of Sweden and Norway	Cambrian (upper)
223.	St. Cassian or Hallstadt beds	Trias (upper)
224.	Tarannon shales (Wales)	Silurian (upper)
225.	Tufaceous strata of Sicily	Pliocene (newer)

	SUBFORMATION.	SYSTEM.
226.	Tuff, volcanic, of Madeira	Miocene (upper)
227.	Tongrian beds of Belgium	Ditto (lower)
228.	Travertin Inférieur	Eocene (upper)
229.	Thanet sands, or Woolwich beds	Ditto (lower)
230.	Tealby series of Lincolnshire (Necc. M.)	Cretaceous (lower)
231.	Turonien middle chalk	Cretaceous
232.	Touraine Faluns	Miocene (upper)
233.	Woolwich beds, or Thanet sands	Eocene (lower)
234.	Wealden beds of Hanover, Surrey, Kent, Sussex, &c.	Cretaceous (lower)
235.	White chalks of France, Sweden, and Russia	Ditto (upper)
236.	Do. with flints (upper), without flints (lower) British	Ditto
237.	Woolhope limestone and grit (N. and S. Wales)	Silurian (upper)
238.	Wenlock limestone and shales (N. and S. Wales)	Ditto
239.	White crag (coralline crag)	Pliocene (older)
240.	Yoredale series of Yorkshire	Carboniferous (upper)
241.	Zechstein	Permian

N.B.—The above numbers *prefixed* to a mineral indicate the subformations in which it is most commonly found.

Table XII.—Characteristic Fossil Species in Principal Geological Subformations.

(Compiled chiefly from Penning and Lyell.)

The following table is intended to supply an additional aid in the mineralogical use of Table XI., and thus to assist the geologist in the pyrological as well as the palæontological determination of "horizons" or "zones." An illustration of this purpose will be best afforded in the words of Professor H. A. Nicholson (Nicholson's "Palæontology," vol. i. p. 37, last edition): "We often meet with cases in which a formation, even if essentially homogeneous in its mineral nature, can be divided into *Zones*, each of which is characterized by the possession of special groups of fossils. The most celebrated of such cases is that afforded by the *Lias.*

This great and essentially argillaceous formation can be divided into a number of zones, each of which is characterized by possessing some special fossils, and particularly by some special ammonite. These zones are extremely constant, and they are traceable wherever the formation is fully developed and has been fully examined in Europe, so that they enable us to effect a division of the formation into special horizons which have no stratigraphical existence, and are not separated by any physical break. . . . . The principal difficulty that we have to confront in dealing with these 'zones' is to produce any plausible explanation accounting for the destruction of the special life-forms of the one zone and the appearance of those of the next zone."

Now it seems to me that the delicate pyrochemical analysis of the mineral matter of such "zones," possible by the blowpipe, would, perhaps, in some measure, solve this difficulty (and probably some others) of geologists and palæontologists, and show that there is a "physical break" of matter corresponding to the fossil demarcations, and that the formation in reality is not "essentially homogeneous." The prefixed numbers of course correspond to those of Table XI.

9. 24. Asaphus Powisii—Echinosphærites Balticus—Holopea Concinna —Illænus Bowmanni—Leptæna Sericea—Lituites Cornu-arietis—Orthis Vespertilio—Orthis Flabellulum—Phacops Apiculatus—Trinculeus Concentricus.

12. 152. Bulimus Ellipticus—Chara Tuberculata—Melania Turritissima—Melanopsis Carinata—Paludina Lenta—Planorbis Discus.

17. 172. Auchenaspis Salteri—Atrypa Reticularis—Cephalaspis Murchisoni—Calymene Blumenbachii—Chonetes Striatella (lata)—Favosites Gothlandica—Heliolites Interstincta—Linglula Cornea —Onchus Tennistriatus—Orthis Elegantula (lunata)—Phacops Caudata—Proëtus Latifrons—Platychisma Helicoides—Pteraspis Banksii — Pterygotus Ludensis — Rhynconella Wilsoni — Strophomena Euglypha—Strophomena Depressa.

13. Cardita Planicosta—Ceritheum Giganteum—Conus Deperditus—

Litharea Websteri—Nummulites Lævigata—Turritella Imbricataria.

18. Banksia Longifolia—Carpinus Grandis—Cinnamomum Lanceolatum—Corylus Grosse-dentata—Lastria Stiriaca—Sabal Major—Sequoia Couttsiæ—Sequoia Langsdorfii.

28. 30. 132. Ammonites Varians—Ammonites Rhotomagensis—Belemnitella Plena—Holaster Subglobosus—Lima Globosa—Pecten Beaveri—Terebratula Semiglobosa—Turrilites Costatus.

63. Baculites Faujasii—Brachyurus Rugosus—Hemipneustes Radiatus—Nautilus Danicus.

231. Ammonites Peramplus — Discoidea Cylindrica — Echinoconus Subrotundus — Inoceramus Labiatus — Ptychodus Decurreus—Rhynconella Cuvieri — Terebratulina Gracilis — Ventriculites Radiatus.

31. 182. Ananchytes Ovatus—Belemnitella Mucronata—Echinoconus Conicus—Inoceramus Brogniartii—Lima Hoperi—Micraster Coranguinum — Parasmilia Centralis — Rhynconella Octoplicata — Spondylus Spinosus—Terebratula Cornea.

36. Chama Squamosa—Conus Dormitor—Crassatella Sulcata—Fusus Longævus—Nummulites Variolaria — Pleurotoma Colon—Rostellaria Rimosa—Voluta Luctatrix.

38. 151. Apiocrinus Parkinsoni—Ceromya Concentrica—Cylindrites Acutus—Patella Rugosa — Purpuroidea Morrisii — Rhynconella Concinna—Terebratula Digona—Trigonia Goldfussii.

33. 147. Ammonites Deshaysii—Ancyloceras Gigas—Crioceras Duvalii —Diceras Lonsdalei—Exogyra Sinuata—Gervilia Anceps—Meyeria Vectensis—Pecten Cinctus—Perna Mulleti—Terebratula Sella —Trigonia Caudata.

40. Aturia Ziczac—Nautilus Centralis—Nummulites Planulata—Pholadomya Margaritacea—Rostellaria Ampla—Vermicularia Bognoriensis—Voluta Nodosa—Zanthopsis Tuberculata.

41. 77. Aporrhaïs Parkinsoni—Ammonites Lautus—Ammonites Auritus — Ammonites Interruptus — Belemnites Minimus — Hamites Intermedius — Inoceramus Concentricus — Nucula Pectinata — Solarium Ornatum—Trochocyathus Conulus.

39. Ammonites Biplex—Ammonites Mutabilis—Exogyra Virgula—Patella Latissima—Pliosaurus—Rhynconella Inconstans—Thracia Depressa—Trigonia Clavellata.

42. Alaria Composita—Ammonites Cordatus—Ammonites Excavatus —Ammonites Lamberti—Belemnites Puzozianus—Gryphæa Dilatata—Myacites Recurva—Trigonia Costata.

59. Astarte Omalii—Cardita Senilis—Flabellum Woodii—Fascicularia Aurantium—Pecten Opercularis—Terebratula Grandis—Theonoa Globosa—Voluta Lamberti.

148*a*. Astarte Borealis — Natica Helicoides — Nucula Cobboldiæ—Rhynconella Psittacea—Scalaria Greenlandica—Tellina Obliqua.

159. Balanophyllia Calyculus — Cardium Augustatum — Fusus Contrarius — Nassa Reticosa — Pectunculus Variabilis — Purpura Tetragona.

58. Ammonites Perarmatus — Chemnitzia Heddingtonensis — Cidaris Florigemma — Echinnobrissus Scutatus — Thamnastrea Arachnoides—Thecosmilia Annularis.

58*a*. Ammonites Achilles—Ammonites Tenuilobus—Astarte Supracorallina — Cardium Corallinum—Cidaris Florigemma — Diceras Arietina—Hemicidaris Crenularis—Terebratula Moravica.

60. 128. Acrosalenia Hemicidaroides—Avicula Echinata—Holectypus Depressus—Nucleolites Clunicularis—Terebratula Intermedia—Terebratula Lagenalis.

48 to 55. Alethopteris Lonchitica—Anthracosia Phillipsii—Anthracosia Acuta, Robusta, &c.—Calamites Suckovii—Cythere Inflata—Lepidodendron Sternbergi—Megalichthys Hibberti—Neuropteris Gigantea—Sigillaria Reniformis—Spirorbis Carbonarius.

67 (Lower). Alveolites Suborbicularis—Homalonotus Armatus—Orthis Arcuatus—Phacops Laciniatus.

67 (Middle). Bronteus Flabellifer — Calceola Sandalina — (Goniophyllum) Cyathophyllum Cæspitosum—Favosites Cervicornis—Heliolites Porosa—Megalodon Cucullatus—Stringocephalus Burtini—Uncites Gryphus.

67 (Upper). Clymenia Linearis—Cucullela Hardingii—Cypridina Serratostriata—Goniatites Subsulcatus—Phacops Latifrons—Spirifera Disjuncta.

70. 180. Asaphus Homfrayi — Dichograspus Sedgwickii — Diplograspus Pristis—Ogygia Selwynii—Orthis Carausii—Trinucleus Gibbsii.

71. 72. Agnostus Princeps — Cruziana Semiplicata — Dictyonema Sociale—Hymenocaris Vermicauda—Lingulella Davisii—Olenus Micrurus—Asaphus Tyrannus—Ampyx Nudus—Didymograspus Murchisoni — Diplograspus Foliaceus — Lingula Attenuata — Ogygia Buchii—Rastrites Peregrinus—Trinucleus Fimbriatus.

77. 78. Ammonites Rostratus—Hamites Armatus—Holaster Lævis—Inoceramus Sulcatus—Ostrea Frons—Pecten Asper—Pleurotomaria Rhodani—Rhynconella Dimidiata—Terebratula Biplicata—Terebratella Pectita.

79. 136. Aviculopecten Papyraceus — Discina Nitida — Goniatites Sphæricus, Listeri, &c.—Lepidodendron Veltheimianum—Orthoceras Steinhaueri—Posidonomia Becheri—Producta Scabricula.

87. Arenicolites Didyma—Agnostus Cambrensis—Concoryphe Lyellii—Histioderma Hibernicum — Leperditia Prima — Microdiscus Sculptus—Oldhamia Antiqua—Oldhamia Radiata.

88. Cyrena Obovata — Cytheræa Incrassata — Limnea Longiscata—Melania Muricata—Planorbis Euomphalus—Potamides Concavum.

89. Cerithium Elegans — Chara Medicaginula — Corbula Pisum — Cyrena Semistriata—Paludina Lenta—Rissoa Chastellii—Sequoia Couttsiæ—Voluta Rathieri.

120. Holopella Tennicincta—Illænus Thomsoni—Meristella Augustifrons—Murchisonia Angulata—Petraia Subduplicata—Stricklandinia Lens.

121. Atrypa Hemispherica — Euomphalus Prenuntius — Pentamerus Oblongus—Petraia Bina.

122 (Lower). Ammonites Bucklandi—Ammonites Planorbis—Belemnites Elongatus — Extracrinus Briareus — Gryphæa Incurva—Hippopodium Ponderosum — Rhynconella Rimosa — Spirifer Walcottii.

122 (Upper). Ammonites Bifrons—Ammonites Communis —Belemnites

Tubularis—Cardinia Listeri—Leda Ovum—Rhynconella Cynocephala.

105. Cyclonema Corallii—Lingula Lewisii—Orthoceras Ludense—Pentameras Knightii — Phragmoceras Ventricosum — Pterinæa Sowerbyi—Rhynconella Navicula—Rhynconella Wilsoni.

106. Actinocrinus 30-Dactylus — Euomphalus Pentangulatus — Lithostroteon Junceum—Michelinia Favosa—Orodus Ramosus, &c. —Orthis Resupinata—Phillipsia Pustulata—Platycrinus Lævis—Producta Semireticulata — Rhynconella Acuminata — Spirifera Striata—Terebratula Sacculus.

107. Ananchytes—Catillus (Inoceramus)—Cidaris—Gryphæa (Exogyra)—Hippurites Organisans—Lima—Nucula—Ostrea—Pecten —Certain species of the *genera* Spatangus—Sphærulites—Rudistes Terebratula—Trigonia.

108. 241. Avicula Speluncaria—Axinus Obscurus—Camaraphoria Crumena—Fenestella Retiformis—Lingula Credneri—Nautilus Freislebeni—Producta Horrida—Schizodus Schlotheimi.

130. Equisetites Columnaris—Estheria Minuta—Hyperodapedon Gordoni—Labyrinthodon Jaegeri.

131. 97. Acrolepis Sedgwickii — Cælacanthus Granulatus—Lingula Mytiloides — Neuropteris Huttoniana — Palæoniscus Comptus—Platysomus Striatus.

133. Ammonites Margaritatus — Ammonites Spinatus—Rhynconella Tetrahedra—Terebratula Punctata.

135. Discina Rugata—Grammysia Cingulata—Homalonotus Knightii —Orthonota Amygdalena—Rhynconella Nucula—Phacops Downingiæ.

Eocene Mammals. Anoplotherium Gracile et Commune—Chæroptamus Cuvieri—Coryphodon Eocænus—Dichobune Cervinum—Palœotherium Magnum et Minus.

Miocene Mammals. Acerotherium Incisivum — Anthracotherium Magnum — Dinotherium Giganteum — Hyopotamus Bovinus — Mastodon Augustidens.

Pliocene Mammals. Balænodon Emarginatus—Cervus Anoceros—Elephas Meridionalis—Mastodon Arvernensis—Rhinoceros Leptorhinus—Tapirus Priscus.

137. Agnostus Davidis—Concoryphe Homfrayi—Erinnys Venulosa—Lingulella Ferruginea—Obolella Sagittalis—Paradoxides Davidis Theca Corrugata.

138. Ceratites Nodosus — Encrinus Liliformis — Gervilia Socialis—Nautilus Hexagonalis—Placodus Gigas—Terebratula Vulgaris.

153. Acer Trilobatum—Cinnamonum Polymorphum—Glyptostrobus Europæus—Hakea Salicina—Platanus Aceroides—Smilax Sagittifera.

154. Cerithium Portlandicum — Isastrea Oblonga — Lucina Portlandica—Trigonia Gibbosa.

155. Archeoniscus Edwardsii — Cycadeoidea Microphylla — Cypridea Tuberculata—Lepidotus Minor—Ostrea Distorta—Pleurosterum Ovatum.

164. Avicula Contorta—Cardium Rhæticum—Gyrolepis Tenuistriatus —Hybodus Plicatilis—Pecten Valoniensis—Saurichthys Apicalis.

173. 233. Cerithium Funatum—Corbula Longirostris—Cyprina Mor-

risii—Cyrena Cuneiformis—Melania Inguinata—Ostrea Bellovacina.

168. Æthophyllum Speciosum—Cheirotherium Barthi—Nothosaurus Schimperi—Voltzia Heterophylla.

170 (Lower). Cephalaspis Lyellii—Phacops Laciniatus—Pteraspis Lloydii—Pterygotus Anglicus.

170 (Middle). Asterolepis Ormusii—Diplacanthus Gracilis—Glyptolepis Elegans—Osteolepis Major—Phyllolepis Concentricus—Pterichthys Major.

170 (Upper). Anodonta Jukesii—Coccosteus Decipiens—Cyclopteris Hibernica—Cyclostigma Minutum—Holoptychius Nobilissimus.

166. 171. Acanthodes Gracilis—Calamites Gigas—Callipteris Conferta—Palæoniscus Blanvillei—Walchia Piniformis—Unio Tellinarius.

175. Ctenodonta Tumida—Cucullela Hardingii—Modiola Macadami—Rhynconella Pleurodon—Spirifera Cuspidata—Streptorhyncus Crenistria.

177. Acervularia Luxurians—Acidaspis Barrandii—Euomphalus Discors—Omphyma Turbinatum—Orthis Rustica—Orthoceras Annulatum—Pentamerus Galeatus—Periechocrinus Moniliformis—Pterinea Retroflexa—Retzia Cuneata—Spirifer Plicatellus—Rhynconella Borealis.

178. Atrypa Grayi—Homalonotus Delphinocephalus—Illænus Barriensis—Meristella Didyma—Pentamerus Linguifer—Retzia Barrandii—Spirifer Exporrectus.

181. Angelina Sedgwickii—Concoryphe Depressa—Modiolopsis Solvensis—Neseuretus Ramsayensis—Niobe Homfrayi—Theca Operculata.

232. Cardita Jouanneti—Lamna Contortidens—Ostrea Crassissima—Pleurotoma Tuberculosa—Scutella Faujasi—Voluta Lamberti—Voluta Rarispina.

N.B.—In pronouncing the above names from the Latin, *a* is pronounced as a in "part;" *e*, as a in "pay;" *i*, as ie in "piece," except where these vowels are obviously short. The student is recommended to make or procure even rough sketches of the fossils indicated, and to keep them by him for reference. Engravings of very many of them are to be found in "Woodward's Manual of the Mollusca," Crosby Lockwood & Co.

Table XIII.—Of the Blowpipe Treatment and Reactions of Ordinary Rocks.

Apatite	Tab. VI.—38–4
Augite (Var.-Diallage)	Tab. III.—40· 1· 24· 28·5
Basalt	Tab. VI.—48—4. Tab. III.—1·
Chlorite—Schist	Tab. III.—27·5 1· 56· 24· 28·5
Dolerite	Tab. III.—40· 1· 56· 24· 28·5 50·35
Dolomite	Tab. III.—40· 12· 24. Tab. III.—1
Felsite	Tab. VI.—48–4. Tab. III.—1·
Fuller's earth	Tab. III.—27·5 1· 28·5

Gneiss	Tab. VI.—48-4. Tab. III.—1·
Granite	Tab. VI.—48-4. Tab. III.—1·
Hornblende	Tab. VI.—48-4. Tab. III.—1·
Hypersthene	Tab. VI.—48-4. Tab. III.—1· 56· 24· 28·5
Mica-Schist	Tab. III.—2·75 1· 28·5
Obsidian	Tab. VI.—48-4
Phonolite (Clinkstone)	Tab. VI.—48-4
Porphyrite	Tab. VI.—48-4
Pumice (Lava froth)	Tab. VI.—48·4
Quartz (vars. Flint, Hornstone, Chert)	Tab. III.—28·5
Quartzite (altered quartz sandstone)	Tab. III.—40· (tr.) 28·5
Rock-Salt	Tab. III.—35·5 23·
Sandstone (Micaceous)	Tab. III.—27·5 28·5
Serpentine	Tab. III.—1· 24· 28·5
Slate	Tab. III.—27·5 1· 28·5
Steatite	Tab. III.—1·24 28·5
Syenite	Tab. VI.—48·4
Talc-rock (Quartz, Felspar, Talc)	Tab. VI.—48·4
Trachyte	Tab. VI.—48·4

The two following chapters are in the form of a dialogue between the upholders of the old and new systems of anhydrous analysis. This form is adopted because it is hoped that an impartial comparison between the merits of the two systems will thus be presented to the candid student in the manner best impressing on his attention, dry, but necessary details; while the most interesting and novel facts are thus enabled to be strongly marked and highly coloured.

CHAPTER X.

*INNER CALCIUM-PYROBORATE BALLS,** "*CHEMICAL WATER,*" *ETC.*

ALLOW me now, the whole preliminary way to our work having been cleared, to introduce to the reader my three typical students, Messrs. A., B., and C., who shall represent respectively English, and Freiberg, or New Jersey students.

Mr. A. is the type of my model students: sharp, attentive, judicious, diligent, and careful—A-1 at the pyrological Lloyd's, in fact. B. is a very good example in the way of students also, patient and hard-working, but *rather* dull. Herr (or Mr.) C. is either a Freiberg Professor who speaks English and German with equal fluency, or a New Jersey American lately from Freiberg (soon proves to be the latter). Some people even say he has been specially deputed from either or both of those places in order to "see if there is anything in these new methods." At all events, he is a man of excellent talents, and a splendid manipulator with the mouth-blower, but "wedded" to the old, time-honoured system of analysis—borax, charcoal,

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* A paper on this subject, declined by Section "B" of the British Association at Swansea, in 1880, was translated into German and read a fortnight later at Dantzic, before the German Association, by Professor Gilbert Wheler, of Chicago, who procured the paper from me for the purpose.

"outer flames," &c.—which I have permitted him to solely employ here, on condition he uses none of the fluid, violent acids, which certainly form no part of *Blowpipe* manipulation. The students are seated at three well-separated tables, so that they cannot see each other's work; A. and B. have the apparatus and reagents, &c., around them, described in previous chapters, and C. has a complete and beautiful set of Plattner's apparatus made by Lingke, of Freiberg (*barring* the bottles of acids, which have been removed), with a copy of Professor Cornwall's lately-published book, "Blowpipe Analysis and Determinative Mineralogy." "Gentlemen" (I say by way of prefatory address) "we shall, of course, commence with the easiest subjects; and the only further observation I have to make is, that I have placed that clock full in sight of all, to remind you that *rapidity* in Blowpipe Analysis is of almost equal importance with *correctness*." Example 1.—White, opaque, amorphous fragments (evidently of some mineral). All three tried the *hardness* with a penknife point, in spite (or contempt) of "Moh's Scale of Hardness," which is as follows,—

2. Rock Salt or Gypsum will scratch Talc. 1.
3. Calcite will scratch Gypsum.
4. Fluor-spar will scratch Calcite.
5. Apatite will scratch Fluor-spar.
6. Orthoclase will scratch Apatite.
7. Quartz will scratch Orthoclase.
8. Topaz will scratch Quartz.
9. Corundum will scratch Topaz.
10. Diamond will scratch Corundum.

and is far more correct than the trial with a penknife, the point of which is turned by the first harder mineral it is drawn across. A. brought his work (boric and phosphoric acid beads) up in ten minutes; B. in about twenty; and C. did not come at all, but said "he thought he could guess what the mineral was, though he could not *prove* it without HCl (hydrochloric acid), ammonia, and ammonium carbonate." A.'s notes were as follow:—" 1. Powder in boric acid O.P.; about half, opaque white fragments, evolving grey opaline matter into the bead on continued O.P.; about five-elevenths—or the right side of square 11, Fig. 113; transparent balls, slightly opaline hot, transparent pale green cold, and evolving grey opaline matter (*combined water*) into the bead in continued O.P., in consequence of inner transparent balls (Fig. 117), looking like surface crystals on the balls through a weak lens. (About half *silica*; no *alumina;* about 45 per cent. *lime,* with *calcium silicate*—the inner balls—and traces of *magnesia* and *iron protoxide*); one or two minute, brown, transparent balls, colourless, after H.P., (trace of *manganese*). 2. Powder in pink P. acid P.P., about half undissolved (about half *silica;* consequently no *alumina,* because all undissolved fragments in (1) are also undissolved here); bead remains pink (no alkali or alumina). 3. Presence of *lime* confirmed by E.P., on a candle pyrocone—see Table II.—when there was a strong red-orange 'mantle' (*lime*); also by cobalt solution, *after* O.P., which turns a fragment blue." "I therefore consider" (A. appended to his notes) "that this mineral is ordinary calcium-silicate, or *Wollastonite.*"

B.'s notes were rather confused. He, too, concluded the mineral to be calcium-silicate, but said "he thought, from the opacity of the bead, there must be alumina present." He "had not tried the powder in pink P. acid"— which would have confirmed the absence of alumina.

Mr. C. stated, "The fusibility B.B. of this mineral is from 1 to 5—certainly not over 5; it fuses to a semi-transparent glass, with a slightly orange flame (trace of sodium). It may be *Pectolite, Analcite, Apophyllite* (although scarcely sufficient intumescence in fusion for that), *Wollastonite, Meionite, Melilite, Cancrinite, Barsowite,* &c." (1. *b.* Cornwall's "Determinative Mineralogy," New York, 1882.) "I should of course have distinguished these had you allowed the use of acids, by observing whether they gelatinised perfectly or imperfectly with HCl.

"Answer," written on the blackboard, was as follows:—

Mineral (85, 105, 110, also in granite and lava), *Wollastonite,* analysed by Wiehage (Dana's "System of Mineralogy," 1877, p. 211). Silica (SiO_2), 51·90, iron protoxide (FeO) with manganese monoxide (MnO) 0·96, magnesium oxide (MgO, magnesia) 0·65, calcium oxide (CaO, lime) 46·44 = total 99.95. N.B.—In future, chemical formulæ alone of mineral constituents will be given. An alphabetical explanatory list of the more important chemical combinations is appended.

Mr. C.—"I should like to see how your razor-like follower here (A.) got that 'red-orange' flame? I *tried* the mineral for that, and couldn't get anything more than orange without the red."

"Simply by touching one side of the candle-wick with the freshly-calcined mineral, held in pt. forceps *whilst* the blue blowpipe pyrocone (or 'flame' as *you* call it) is being produced—thus."

C. (*surprised*).—"Well, now, I call *that* an improvement; I shall send a note of that to The States, sir." (To A.) "I see, sir, from your notes, that you find 'combined water' in *Wollastonite;* now all mineralogists maintain—and I maintain—that it 'yields little or no water.'" (Cornwall, p. 284).

"Allow me, Mr. C." (said I), "to explain this matter instead of my pupil, and to add that it affords me a pleasure and gratification I can scarcely express in words to have the opportunity of so explaining this most interesting and novel fact to a pyrological chemist of your ability and candour. You see here I have got a blowpipe assay balance in glass and mahogany frame (a very good though a small one, which obtained a prize at a German scientific exhibition, made by Neumann, who preceded Lingke, and from whom I purchased it, at Freiberg, in 1867), and a binocular microscope. Well, now, follow me while I calcine B.B., a piece of this clean eggshell till it glows white-hot, crush it to fine powder between agates, and apply precisely 5 mgrs. (milligrammes) of it very carefully to this bead of pure boric acid, B.B.; the result, as you see, is a still perfectly transparent *bead*, containing several equally transparent and colourless *balls*, (Fig. 116), which after a few more seconds' treatment before the blowpipe, coalesce into one ball. Throwing the bead and contained ball, with its wire ring, into this capsule of boiling water (H, Fig. 21), in a few seconds I obtain the ball *per se*, and weighing it in my balance, find it is exactly *four times* the weight of the freshly calcined lime powder used to make it—viz. 20 mgrs. I have done this numberless times with the same result. You

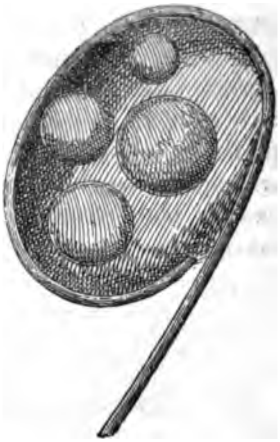

Fig. 116.
Calcium-Borate Balls.

will, therefore, readily admit the fact that anhydrous calcium-pyroborate consists of 25 parts of caustic lime and 75 parts of pure boric acid.

"Watch me closely, now, while I calcine and crush some more eggshell, hydrate it with a few drops of distilled water until all steam has stopped; very gently dry the hydrate on warm Al plate till the superfluous water is evaporated and no more; weigh 5 mgrs. of it and apply the same, B.B., to another bead of pure boric acid. Mark the difference! The *bead* is no longer transparent as before, but almost opaque with grey opaline matter, evidently obtained from the calcium *hydrate* (slaked and dried lime). But on boiling this opaque bead in the capsule H. you see I still obtain a perfectly colourless, transparent *ball* from its interior, which, however, as you see, only weighs 15 mgrs., or exactly *three times* the weight of the calcium hydrate taken to make it."

Calcium hydrate composition calculated from these results is	CaO 75·0 H_2O 25·0
Calcium hydrate composition calculated from chemical equivalents is	CaO 75·7 H_2O 24·3

C. "This seems important; allow me to make a note of it."

"Certainly, sir, if you wish it." C.—"Have you observed, sir, by the two formula obtained from your results—CaO 25·0 B_2O_3 75·0 (calcium borate) *and* CaO 75·0 H_2O 25·0 (calcium hydrate), that the 'chemical water,' as you call it, has only *one-third* the combining power of boric anhydride—*i.e.* that three times as much of boron trioxide as of the former can combine with lime; therefore, if you take the combining weight of oxygen as 16 and of hydrogen as 1, you will have $16 \times 4 = 64$ (the nearest multiple to $75-3H$ or 72), or O_4 and 11 H (say 12 H for an equal multiple), that is, $H_{12}O_4$, or, in simplest form, H_3O as the symbol?"

"Yes, sir, I did remark this apparent confirmation of these results; but I took the old weight of oxygen, 8, as my basis (that being more convenient), which makes the formula of 'chemical water' H_3O_9, or, in simplest form, HO_3.

"You will now be perhaps unwilling to deny that this 'grey opaline matter,' communicated to anhydrous boric acid B.B. by *hydrated* lime, and *not* by freshly calcined lime, is due to combined or 'chemical' water; and you would also, I presume, be not indisposed to analogically admit that similar 'grey opaline matter,' communicated B.B. to anhydrous boric acid by other mineral substances than lime, is probably also due to combined water; more especially if, with the opaline boric-acid bead thus produced, you can *rehydrate* freshly calcined lime, so as to make it *then* afford an opaque bead before the blowpipe?"

C.—"Certainly."

"Mark me then, while I treat 5 mgrs. of this pure silica from Görlitz; or, if you prefer it, I will take pure crushed 'rock-crystal'—the 'glass' of one of your spectacles, for instance."

C.—"No, thank ye, sir; the Görlitz silica will suit me exactly."

"Well, as you see, the prolonged treatment of this weighed silica in a bead of pure boric acid in the hottest 'flame' (as *you* call it) of the hot-gas lamp with foot blower (Fig. 21) has not the slightest effect upon the contained silica, or on the transparency of the containing bead. If necessary, I could boil out this silica from the bead, and re-weigh it to prove the fact (as I have often done before), but you may take my word for it.

" I now add to this silicious bead B.B., the anhydrous calcium-borate ball we extracted from the boric-acid bead in our first experiment, and found to weigh 20 mgrs.

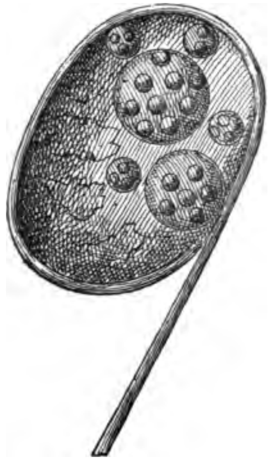

Fig. 117.—Inner Borate-Balls formed by Silica.

" See! 'Grey opaline matter' immediately begins to be evolved *from the silica* (for we before found this anhydrous calcium-borate ball to float *quite transparently* in its containing bead, Fig. 116, and, therefore, it can communicate no opaline matter whatever to the latter), until the bead becomes all but opaque; precisely as A.'s *Wollastonite* bead was opaque. I now boil out the silica, dry, and weigh it. You see it only weighs 3 mgrs. now, whilst the weight of the calcium-borate ball is still exactly 20 mgrs. Repeating this process, I thus obtain another B acid bead, but not nearly so opaque, from this silica, which, extracted as before, now only weighs 2 mgrs. Thus, *more than half* of this pure silica *consists of some hydrogen and oxygen compound*, which we have here called 'combined water.' But this is not all. I now take the 20 mgrs. calcium-borate ball carefully upon a small hook of thin red-hot platinum wire, such as this, and fuse or dissolve in it by O.P. (your O.F.) a very small portion of pure silica powder, so that it is now silicious calcium-borate. I then run it while red-hot down the shank of the wire, straighten the hook, and thus easily run the red-hot ball back again, completely off the wire, upon a clean aluminium tray—thus. I now note the weight of the silicious ball, crush it with forceps, apply the powder to a fresh bead of pure boric acid, B.B., flatten the hot bead on Al plate, and place it with its contents under the ¼-in. objective of this microscope. You will observe that, barring the fragments of free silica, this bead is precisely similar to the *Wollastonite* bead of Mr. A. (Fig. 117), or, in fact, calcium silicate without free silica. I now boil the silicious CaB_2O_4 out of the bead, dry, and weigh it again. Observe that, in spite of the opaline matter evolved, it is considerably *heavier* than before! Considerations as to the apparent cause of the singular formation of these inner balls of silicious calcium-borate must be reserved for another chapter.

Table XIV.—More Important Basic Oxides, &c., Formulæ, with their Combining Weights.

(Compiled from Miller's "Chemical Physics.")

$Al_2 Cl_6$ = 267·7
$Al_2 O_3$ = 103·
$Ag Cl$ = 143·5
$Ag_2 O$ = 232·
$Au Cl_3$ = 232·1
$Au_2 O_3$ = 441·4
$Ba Cl_2$ = 207·8
$Ba O$ = 153·
$Bi Cl_3$ = 316·8
$Bi_2 O_3$ = 464·
$Ca Cl_2$ = 111·2
$Ca O$ = 56·
$Cd Cl_2$ = 183·2
$Cd O$ = 128·
CH_4 = 16·
CO_2 = 44·
$Co Cl_2$ = 129·8
$Co O$ = 74·
$Co_2 O_3$ = 165·6
$Cr_2 Cl_6$ = 318·
$Cr O$ = 68·5
$Cr_2 O_3$ = 153·
$Cu Cl_2$ = 134·5
$Cu O$ = 79·5
$Ca_2 O$ = 143·
$Fe_2 Cl_6$ = 269·
$Fe O$ = 72·
$Fe_2 O_3$ = 169·
$Fe S$ = 88·
$Hg Cl_2$ = 271·
$Hg O$ = 216·
$H_2 O$ = 18·
$Hg_2 O$ = 416·
$K H O$ = 56·
$K^2 O$ = 94·
$L_2 O$ = 30·
$L Cl$ = 78·
$Mg Cl_2$ = 95·6
$Mg O$ = 40·
$Mn Cl_2$ = 126·1

$Mn\,O$ = 71·
$Mn\,O_2$ = 87·
$Mn_2\,O_3$ = 158·
$Na\,Cl$ = 58·5
$Na_2\,O$ = 62·
$Na_2\,HO$ = 40·
$Ni\,O$ = 74·8
$Ni_2\,O_3$ = 165·6
$Ni\,Cl_2$ = 129·8
$Pb\,O$ = 223·
$Pb\,Cl_2$ = 278·
$Pt\,O$ = 213·4
$Pt\,Cl_4$ = 339·1
$Pt\,O_2$ = 229·4
$Sb\,Cl_3$ = 228·5
$Sb_2\,O_3$ = 292·
$Sb_2\,O_5$ = 324·
$S\,H_2$ = 34·
$Sn\,Cl_4$ = 260·
$Sn\,O$ = 134·

$Sn\,O_2$ = 150·
$SO_4\,H_2$ = 98·
So_2 = 64·
$Sr\,Cl_2$ = 158·2
$Sr\,O$ = 103·5
$Ta_2\,O_5$ = 355·
$Tl_2\,O$ = 424·
$Ta\,F_5$ = 232·5
$Ti\,O_2$ = 82·3
$Tl\,Cl$ = 239.5
$U_2\,O_3$ = 288·
$Ti\,Cl_4$ = 192·3
$V\,Cl_6$ = 350·1
$V\,O_3$ = 185·1
$W\,O_3$ = 232·
$Zn\,O$ = 81·
$Zn\,Cl_2$ = 136·
$Zr\,O_2$ = 121·5
$Zr\,F_4$ = 165·

Examples of the way to use the above Table, with the Atomic Weights quoted in Table III. (Valentin).

How much Copper Monoxide can I obtain by the oxidation of 100 *grs. of Copper ?*

63·5	:	79·5	: :	100
At. Wt. of Copper.		Wt. of Molecule of Cu O.		Grs. of Cu

63·5) 79500 (125·196 grs. of Cu O
635
1600
1270
3300
3175
1250
635
6150
5715
4350
3810

How much Copper when 100 *grs. Cu O are reduced in a current of hydrogen?*

79·5	:	63·5	: :	100
Wt. of Molecule of Cu O.		At. Wt. of Copper.		

795) 63500 (79·874
5565

7850
7155

6950
6360

5900
5565

3350
3180

Distillation of Water in the Field.

A rough but effective mode of obtaining sufficient distilled water to fill the dropping bottles (Figs. 69, 70) is as follows:—

Have an extra lid to your saucepan, and keep it clean, reserved for this purpose, marked "A." Boil the purest obtainable water in the well-cleaned saucepan, and, when boiling has begun, cover it with "A" having a towel wet with *cold* water fastened on it. In a few seconds the inside of "A" will be covered with drops of condensed water, which are to be poured (through a funnel) into *b*, Fig. 70. A repetition of this process will soon fill the bottle.

CHAPTER XI.

RATIONALE OF OUTER AND INNER BALL FORMATION. —SODIUM AND NON-SODIUM YELLOW FLAMES.—CAUSE OF THE COLOUR OF SAPPHIRE, EMERALD, AMETHYST, ETC.

C.—"BEFORE proceeding, would you kindly say if it is *necessary* to crush the silicious calcium-borate ball before adding it B.B. to the boric acid, in order to produce the inner balls?"

"Certainly not. You can apply the weighed silicious ball, just as it is, to fresh B. acid, B.B., and almost immediately obtain the inner balls."

C.—"But how do you explain the formation of these 'inner balls' communicated to calcium pyroborate by silica; and, indeed, that of the *outer* balls also?"

"The small sphericles or balls formed within a bead by the application B.B. of lime and about twelve other oxides to boric acid, are evidently due to the respective *cohesion of two liquids*—liquid, of course, only when in a state of fusion B.B.—which do not dissolve each other (although that is not the opinion of some chemists), but possess nearly the same specific gravity; just as this oil, poured into diluted alcohol, remains suspended within it in the forms of perfectly spherical masses. The two liquids in the case of lime applied B.B. to boric acid, are the latter (containing), and calcium borate (contained). The boric acid coheres to as near a sphere as the platinum-wire ring to which it clings will allow, and hence the advisability of making the ring as nearly round as possible. The calcium borate coheres to as many perfect sphericles inside the bead as there are fragments of lime applied; and these sphericles are immediately resolved into one by O.P. applied to the containing bead. It is usually supposed that the two liquids, in an experiment with fluids, *must* be of '*precisely* the same specific gravity.' ('Miller's Chemical Physics,' page 65), but that is not *necessary;* for, you see, here is a sphericle of pure gold floating in the boric acid bead B.B. in exactly the same manner as the calcium borate sphericles float."

C.—"This is quite clear; and, as you have shown the contained spheroidal borates to consist of materials in *definite proportion* to each other—both interesting and important to my mind; but I do not yet see why or how *calcium silicate* forms inner balls in *calcium* borate B.B. Why does not the lime of the former combine with or rather join the lime of the latter, and dissolve the silica transparently in the ball, as you showed us it did when the ball was held *per se* on a platinum-wire hook B.B.?" "Your observation shows that you are following me closely, and this is precisely the difficulty as regards the *nature* of these inner balls which occurred to myself. In the absence of a menstruum (at present) for dissolving the outer, and thus obtaining for examination the inner balls *per se,* which will no doubt one day be found (Prof. G. G. Stokes, Sec. Royal Society, recommends me to try *acetic acid,* which I intend doing), I attempted to come to some definite conclusion regarding their nature by a process of ratiocination, and argued thus: "If," said I to myself, "these inner balls are silico-borate of calcium, balls will be formed, when pure silica is applied to the calcium borate, held *by itself* on a platinum wire, without the containing bead of boric acid B.B.; and this we have seen is *not* the case. If, on the contrary, fresh boric acid derived from the outer containing bead is *absolutely necessary* for their formation, the presumption must be that calcium borate cannot be decomposed either by separate or dissolved silica, in boric acid, B.B.; or, in other words, that the calcium borate will not give up any part of its proportion of boric acid to the calcium silicate in order to form inner balls, or any part of its lime to combine with the silica; and that the originally added silica, therefore, is simply dissolved in the ball *per se*, and changed in its nature through the abstraction of its 'chemical water' by the action of calcium borate at this high temperature upon it. The silica then gradually becomes, as it loses this water, in a manner, *itself* 'caustic,' and capable of forming, at high temperature, a fusible compound with boric acid, which compound follows the law of cohesion of liquids while fluid and undissolved in the calcium borate; just as you see this speck of hard marble, when applied B.B. to a boric acid bead, at first appears (like silica) as an unacted-upon white opaque fragment; but shortly losing its CO_2 and 'chemical water' (which latter *immediately shows itself as grey opalescence* in the bead), it forms a fusible compound, and appears as a transparent ball of calcium borate (Fig. 116), instead of a white opaque fragment of calcium carbonate in the bead."

C.—"But, do you mean to say you think you have, in the formation of these inner balls, formed a new substance, hitherto unknown to chemists—*i.e.*, *silicon borate?*" "Most certainly. If you do not conclude it to be that from the full consideration of these experiments and results, will you kindly afford a clue to *any other* explanation of the phenomena? I consider that not only one new substance (silicon borate) has been here proved to exist, but that another substance (pure silica, or 'rock crystal,')—although not 'new' to chemists in one sense, has been hitherto partially misunderstood by them as to its nature (it being in reality a *hydrate*), in consequence of their solely employing, in its analysis, *hydrated* acids." C.—"What do you mean by that last expression?" "I will make you explain it to yourself. You have seen, beyond all doubt, that what I have termed 'chemical water' causes the evolution of grey opalescent matter in boric acid B.B.?" C.—"Certainly, I am quite assured of that fact." "Well, now, will you be so good as to fuse a bead of this pure boric acid upon this ring of new, clean platinum wire? You observe that, when cool, it is as transparent, colourless, and refractive as the 'rock crystal' of your spectacles itself. Now, dip that bead, in a state of red-heat, into this beaker of distilled water, and heat the bead again B.B. What do you observe in it?" C.—"Nothing; the bead is lessened in bulk, in consequence of the bursting of the innumerable bubbles of steam formed, but it is now as transparent and refractive as before." "Now, mark! I pour just a little sulphuric, or nitric, or hydrochloric acid into the beaker of distilled water, and stir it well round with this perfectly clean glass rod. Be so good as to dip your red-hot bead again into this acidulated water, and, after heating B.B., and cooling, tell me the result?" C.—"The result is, faint streaks of grey, opalescent matter, which, on further heating and cooling, *render the whole bead slightly opaline*, and I see now what you mean by the expression 'hydrated acids.' It seems to me, therefore (adopting your views, which I don't say I wholly do yet), that if we treat calcium borate (or the anhydrous contained ball) *separately* with silica in a boric acid bead B.B., the combined lime, *only during the continuance of high temperature,* has an attraction for the supposed 'water' of the silica, and extracts it, itself becoming *hydro*-borate of calcium *only during the period of high temperature,* giving up the thus-obtained 'chemical water' on cooling, to the surrounding boric-acid bead, where it (the chemical water) floats undissolved as a finely-divided precipitate on becoming cold (for I see the whole bead is perfectly transparent whilst hot), which you call 'grey opalescent matter,' but which I should certainly call '*hydrated boric acid*'——" "My dear sir"—"Stop a bit; I haven't done yet. If we admit all this, it seems to me to follow that if you dissolve 'hydrated' (or ordinary) silica in calcium borate held *per se* on a platinum hook and then treat the silicious ball in a boric acid bead B.B., the lime of the ball, caustic in spite of its combination with boric acid *at high temperature,* and *then only* capable of forming the double combination with this water and boric acid which I will call 'Calcium hydroborate' (only existing at high temperatures) extracts the water, as in the other case, from the silica; although in *this* case, the silica, being contained within the ball, cannot escape into the *bead,* but there, *i.e.* within the ball, forms the fusible compound with boric acid obtained through the ball from the outer bead of which you speak, and, assuming the spherical shape whilst fused and liquid, in obedience to the law of cohesion, appears, finally, as 'inner balls of silicon borate,' when, of course, the containing ball would be much heavier, in spite of the opaline matter it evolved.

Is this what you mean?" "My dear sir, you have expressed my meaning more clearly than I could myself." C.—"Well now, will you kindly explain, if your conclusion is correct, how it is that the silica, dehydrated (and thus rendered capable, according to your account, of forming 'silicon borate') by the calcium borate ball treated *separately* with it B.B. in a boric-acid bead, does *not* then form 'silicon borate' *separately* in the *bead?*"

"For two reasons: 1st, because the boric acid, with which the inner anhydrous silica combines, is derived from the containing ball, where it must be *absolutely anhydrous;* the ball meanwhile supplying its loss with boric acid from the containing *bead* in exchange for the water derived from the silica, so that *a round of chemical exchange* goes on. 2nd, because, perhaps, the two fusion-fluids, 'silicon borate' and calcium borate, are suitable for exhibiting the phenomenon of floating spheres (as oil and dilute alcohol are suitable); and the two fusion-fluids, 'silicon borate' and boric acid are *not* suitable (as alcohol and water are not suitable)."

C.—"Well, there is no doubt the inner balls *do* exist (and must be accounted for somehow), for I have just broken a calcium borate ball containing them in half, and placed it under the microscope; and here they are, sticking out of the broken side of the hemisphere. Is silica the only substance which, thus applied, forms inner balls in calcium borate?" "Oh dear no: zirconia, glucina, alumina, tungstic and molybdic acid. In fact, so far as I yet know, *all 'earths' and non-volatile oxides, which do not themselves form balls in boric acid* B.B., form these inner balls. The sublimate of *antimony* forms balls in calcium borate *per se* B.B. with the evolution of 'chemical water.' But the inner balls formed by some oxides, as tungstic acid, *crystallise under continued O.P.*, and these crystals *constantly exhibit the same form*;* which, as you know, is quite the contrary with borax crystals B.B." C.—" Again, this seems to me a matter of some importance." "You stated just now, that I ought to call that fine precipitate, which appears as grey opalescence in the clear B. acid bead, *hydrated boric acid.* Would you suppose, now, that boric acid thus 'hydrated' should have changed any of its properties?" C.—"Certainly I would; and, indeed, I was just going to remark that your boric acid beads, opaque with grey opalescent matter, seem to differ in no respect (except opalescence) from the transparent beads." "What substance, then, would you call this?" (*taking some white powder out of a bottle, and heating it on a platinum spatula under C.'s nose*). C.—"Resin, or some related hydrocarbon." "This, sir," (*fusing the powder B.B. on a pt. wire ring*), "as you see, is opaque, or *hydrated boric acid,* which apparently acquired that peculiar smell of resin by simple exposure to the air, in about a year after it was hydrated in the Royal Artillery Institution Laboratory, Woolwich, in 1873." C. (*reflectively*)—"Are you *quite certain* of this? The resinous smell on ignition is unmistakable; and yet there was certainly no inflammation, as would be the case in thus heating resin. Was this boric acid hydrated with 'water' from silica?" "No, but you see, it also rehydrates calcined lime." (*Calcining to white heat in O.P. of the hot-gas lamp a fragment of pure marble, larger than the opaque bead, upon the latter. The glowing lime slowly clarifies the bead, and, when afterwards separated*

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* The New York scientific Journal called *Science*, contained, in 1880, a wood engraving of a microscopic crystal of Tungsten-borate, published with the paper alluded to above.

from the bead, crushed, and applied to fresh pure B. acid B.B., evolves grey opalescent matter into the transparent bead.) " Follow me in this experiment, and I will show you how this B. acid was hydrated. When I thus make a paste of *calcium hydrate* and dry it as a large opaque bead in gentle P.P. on this pt. wire ring; bend the long wire double, and fuse a bead of pure boric acid upon a similar ring made at the other end of the wire, holding the two beads at the bend of the wire in the forceps so that the 'flame' of the hot-gas lamp, directed upon the Ca hydrate, plays *afterwards* upon the B. acid (Fig. 44), what is it that causes this gradual opalescence in the transparent, colourless boric acid?" C.—"Why, the 'chemical water' of the calcium hydrate; I quite understand that now; there is really no necessity to go through all this *again.*" "Excuse me, sir, that is not my object; but do you observe this yellow flame emitted from the calcium hydrate while it is slowly calcining in O.P., and evidently *causing* the opalescence in the boric acid, by impinging steadily upon the bead, until the hydrate is perfectly calcined and begins to glow white-hot? What is that?" C.—"What is that yellow flame? Why, *sodium,* of course!" "Observe me now, and I will prove to you that it is *not* sodium. Taking the lime-bead off the first ring, I substitute for it a bead of sodium carbonate, and thus, allowing *its indubitable* yellow sodium flame to impinge upon the bead of opalescent boric acid; what is the result?" C.—"*The opalescence removed!* The same cause producing opposite effects—a *reductio ad absurdum*—against Euclid—no, this won't do at all. I admit, sir, that the *first* yellow flame *cannot possibly* be due to *sodium.*" "To what, then, do you suppose it to be due?" C. (*considering*)—"Well, the yellow flame, which rendered the boric acid opalescent, certainly ceased *as soon as* the calcium hydrate was calcined, leaving anhydrous lime behind; this hydrate I have seen to similarly opalesce boric acid, leaving (as was proved by the assay balance) anhydrous calcium borate behind.—Sir, I see no other conclusion except that the *first* yellow flame is caused by the *ignition* of this 'chemical water,' as you call it." "That has been my conviction for twelve years; but you are the first man of science I could get to listen, patiently and intelligently, to my proofs. Some declared they could not understand such simple evidence. Others (very unphilosophically, I think), laughed at me and my proofs, and said I was setting the Thames on fire, &c., &c. But I will now show you how I hydrated this boric acid with the resinous smell on ignition. Taking the bent platinum wire again (Fig. 44), I insert in the ring next the O.P. this little roll of new clean platinum foil, simply to have a considerable quantity, or *bulk*, of platinum in contact with the blowpipe 'flame,' as it then cannot be heated beyond redness, and will consequently, *continuously* emit a yellow flame; *this* yellow flame also, as you see, renders this fresh bead of pure boric acid opalescent, probably, because *red*-hot platinum being known to decompose water (Grove. Corr. Phys. Forces, p. 81), this hydrogen compound is thus eliminated from atmospheric moisture, and attracted by the hot boric acid.

"Well, before I discovered this fact, I fused about four ounces of pure, crystallised boric acid in a clean open platinum dish at a table-blowpipe in the R.A. Institution, Woolwich, with the result of finding all my boric acid grey, opaque, and (as I thought) spoiled! I do *not mean* to assert that you cannot fuse boric acid in platinum *without* producing this result; but I overheated mine, keeping the platinum at a strong red heat for some two hours, and producing, therefore, an enormous amount of this *yellow flame*, which filled the dish, playing upon the boric acid all the time it was being fused. I don't remember it exhibiting this resinous smell on ignition at first, and imagine, therefore, that it was thus rendered capable of gradually absorbing more hydrogen (and, perhaps, carbon) from the air to which it was constantly exposed when the stopper of the bottle was left off. It is this boric acid which has the resinous smell on ignition. I will now show you another curious result of the supposed hydration of boric acid. You see I have got here a stoppered bottle of grey mineral powder. It is pure crystallised *Wavellite*, lately discovered in the country of which you are so justly proud (The States), but baked for a fortnight in my kitchen oven (which you now know better than to suppose would eliminate the 'chemical water,' and which it, in fact, *concentrates*), crushed, and put into this bottle. I purchased this *Wavellite* some years ago, from Henson in the Strand, because I knew it, as aluminium *hydrated* phosphate, to contain a large amount of 'chemical water,' and was curious to see what the effect would be of dissolving its fine powder B.B. in my *hydrated* boric acid, by means of the cautious addition of potassium *hydrate*. You shall now do this yourself; but first I would ask you to test the *Wavellite* for iron or other possible metallic colouring oxide, with the borax you have there, as you do not believe in my reagents."

C.—"Do not say that, sir; I begin now to see the drift of what you call your system, and believe in it; but I will now try this powder, as you suggest, in borax B.B. for the satisfaction of others, and I find the borax bead not even yellow hot; so presume the powder to be so far free from metallic colouring oxides that at all events they cannot contribute any recognisable colour to a bead. Now, what shall I do?" "Fuse some of the resin-smelling boric acid B.B., to a bead on this platinum wire ring, and, taking up on the hot bead gradually some of this baked *Wavellite* powder, with a mere trace of potassium hydrate to dissolve it, treat the mass with a powerful H.P. (you know what that means now) from the 'hot-gas lamp.'" C.—"Why, the bead turns a bright purple!" "Now, dip the hot bead, first in the hydrated boric acid again, and then in the *Wavellite* powder, *plus* a trace of potassium hydrate, and continue the treatment with H.P." C.—"This is really curious. The bead is at first purple, then a beautiful sapphire-like *blue*, and quite transparent; then it becomes an equally brilliant emerald-like *green*." "If you wish it to remain blue, dip it in hydrated boric acid again." C.—"*Dark blue* again. *All* these colours cannot possibly be due to any metallic oxide: cobalt would give a blue bead, copper or chromium a green one, and manganese a purple one; but no single oxide could produce *all three* colours. Did you not communicate this matter to your Royal Society?" "Yes, but the secretary sent me the materials back again, with a note to the effect that he had not time to try them as suggested, but believed the colours of gems, &c., to be due to minute portions of metallic oxides. I then forwarded the packets to HERR PROFESSOR BRUNO KERL, of the Imperial Mining Academy, Berlin, whose chemist (HERR PUFAHL) *did* try them in the laboratory there, and published a leading article on the subject in the *Berg und Hüttenmännische*

Zeitung for 1st December, 1882, headed '*Über die Ursache der Blaufärbung von Saphir,*' &c."

But time and space alike compel me to hasten to a conclusion. (To B).—"You stated 'that you thought, from the opacity of the bead, there must be alumina in *Wollastonite*.' Powder this greyish white, compact, amorphous mineral fragment (of which the only blowpipe analysis given by Cornwall, Dana, and others, is that 'it fuses with intumescence B.B., to a light-coloured mass,' like a hundred other things); treat it in B. acid O.P., and compare the bead it produces with that produced by *Wollastonite* (Fig. 117)." C.—"Why, instead of the balls, inner balls, and fragments of silica, we have here a beautiful bead of *pure white, opaque jewellers' enamel.*" "Something like that, no doubt, but this effect is produced by *alumina*, which, attempting to form inner balls that probably burst before they can exchange their chemical water for boric acid, *decomposes* the calcium-borate balls, and spreads the lime, exactly like 'lime-milk,' over the whole bead; and this is why, in Table VI., you will find the most characteristic reactions of both these oxides (lime and alumina) given, as causing the mutual evolution of 'copious milky matter;' but the student must remember that the *quantity* of *test* added must be exactly proportional to the quantity of *testee* (as a lawyer would call it); that is, if there is only very little alumina present in the mineral, only a trace of lime must be added to the bead, and *vice versâ*. This mineral is (218, 222, and in granite, &c.) *Zoisite*, or calcium silicate *with* alumina. You see, by fusing another fragment of the mineral on Al plate in O.P., and treating the powder in this bead of phosphoboric acid (Table VII., *note*), I obtain the lime in balls again (Fig. 116), because calcium phosphoborate is thus formed, which cannot be decomposed by alumina in boric acid B.B."

I have now only time and space left for one more typical mineral. Grey, or brownish, or greenish fragments (shown in "Cornwall," p. 285, with about fifty others, as "fusing quietly at 3·5"), which, powdered (for I have no time for preliminaries) and applied to B. acid O.P., fuses at bottom of the bead, and forms an ice-like mass, or jelly, in it afterwards. I see, by Table VI., column 4, No. 48, that this indicates an *alkaline aluminous silicate,* the alkali of which is confirmed by added CoO, giving a *pink suffusion* in O.P. (Tables III. and VI.), whilst the alkali is proved to be under 5 per cent. *soda* by the green p.c. of the B. acid not being completely yellowed (Table III.) According to Table VII., No. 6, I now treat powder of the fused fragment, boiled and dried, in phosphoboric acid O.P., and find about four-fifths white, opaque, unattacked fragments (about four-fifths alumina or Al silicate); about one-tenth transparent balls, clear hot, pale green cold (about one-tenth lime, containing iron protoxide: no magnesia); one or two brown-black, opaque balls, with rust-like matter (a very little iron). I now try the original powder in pink P. acid P.P., and obtain about four-sevenths transparent matter undissolved (about four-sevenths silica: consequently, about one-fourth alumina, which could have been confirmed by adding lime O.P. to the first bead, and producing a *white enamel*); bead pinkish *blue* (about 5 per cent. alkali). The mineral is a *constitutent* of some rocks, generally intrusive, *Labradorite.—Analysis by Klaproth* ("Dana," p. 342)—

SiO_2 55·75 Al_2O_3 26·50 Fe_2O_3 1·25 CaO 11·00
Na_2O 4·00 H_2O 0·5 = 99·0.

The following interesting facts should be mentioned here:—

1. A freshly-fused, pure boric-acid bead was fixed on platinum foil, first at the anode and then at the cathode of a powerful Grove battery, placed at my disposal for this purpose, by the kindness of Professor F. Guthrie, F.R.S. It was found to be a non-conductor of electricity, and no result followed.

2. An anhydrous calcium-borate ball, previously ascertained to communicate no opalescence whatever, B.B., to boric acid, was then placed (along with its containing bead) in connection with the battery anode without observable result.

3. But on communicating the same bead (2), having the unchanged calcium-borate ball inside, with the *cathode* of this battery, the contained ball immediately began to develop *grey opalescent matter* into the transparent bead, until the latter became shortly quite opaque.

To the careful student of the many proofs given in this work that this grey opalescent matter communicated to boric acid by calcium-borate, indicates *the presence of some compound of hydrogen,* all commentary on these three facts is unnecessary.

CHAPTER XII.

FREIBERG QUALITATIVE EXAMPLES.

THE following account (on the right-hand side) of these experiments was lent to me in 1860, in his university note-book, by the late Mr. W. Hustler, of Rosemerryn, Cornwall. He was the pupil of Plattner and Richter, at the Freiberg University. Had he lived, there can be no doubt he would have taken a place among the few Englishmen who have distinguished themselves in this field of research by the contribution of original matter to it. Through his knowledge of this science and of geology, he, quite by himself, discovered a valuable deposit of tin ore (*Cassiterite,* I believe), near Orense, in the north of Spain; and leasing the ground, worked some mines there profitably until his death in 1873. He first taught me the use of the blowpipe in 1859, and I can never forget him. I have made no alteration whatever in his experiments, except in the symbolical expression of salts, which I have modernized. The letter "B" represents a glass "bulb," or closed test-tube; "C" charcoal. The unknown substances were given to students by Professor Richter. The left-hand columns consist of analyses on my system.

N.B.—The numbers *above* each mineral refer to its geological position: *vide* Table XI.

1. Powder in B. Acid O.P.	1. A white crystalline powder.
(*a*) Great effervescence with choking smell (*Chlorine* or *Fluorine*). See (*c*).	(*a*) In B gives off H_2O, and loses its crystalline form.

(*b*) Transparent balls evolving opaline matter by continued O.P. (*Barium*).*

(*c*) With copper oxide added O.P. a blue pyrochrome (*Chlorine*).

(*d*) Powder heated with P. Acid in Glass bulb; glass *not* attacked (*no* Fluorine).

N.B.—No S. reaction necessary. Substance could not be *both* a Chloride and Sulphate.

(*b*) On platinum wire, melts, and tinges the flame green (BaO).

(*c*) Dissolves in borax to a colourless bead, which, when a quantity is present, can be flattened. Pearl white (not crystalline).

(*d*) Melted with soda on C and dug out, gives no S reaction. No reaction for CO_2 with HCl and H_2O.

(*e*) With ($KHSO_4$) in B got a pale yellow (Cl).

(The substance is *Baric Chloride.*)

2. Powder in B. Acid O.P.

(*a*) Great effervescence without smell, green p.c. unaltered (*Sulphuric Acid*).

(*b*) Many white opaque balls, transparent after long O.P. (*Magnesium*).

(*c*) Fragment with soda, C slip, H.P. and on Ag. with H_2O a black stain (*Sulphur*): bead, opaque with grey opaline matter† (*much combined water*).

77, 98, 108.

Epsomite.

Analysis by Stromeyer.—SO_3 31·99, MgO 16·49, H_2O 51·20 = 99·59.

2. Transparent crystals.

(*a*) In B gives off much H_2O, changes colour, and sticks to the glass.

(*b*) On C intumesces, remains outside, glowing with a white light while hot: moistened with Co solution in OF turns pink. (MgO.)

(*c*) On Ag. foil, gives S reaction.

(Substance is *Magnesic Sulphate.*)

N.B.—No reason given why this crystal should be tried for sulphur. Co. soln. of no use if any iron present.

3. Powder in B. Acid O.P.

(*a*) Unattacked fragments: as mineral is soft, try for Sulphuric or Phosphoric Acid.

(*b*) Powder fused with Soda on Al plate, boiled, dried, and—

(*c*) in B. Acid O.P. Great effervescence without smell: green p.c. unaltered (*Sulphuric Acid*).

(*d*) Many transparent balls (*Lime*).

(*e*) Fragment in E.P. Strong red-orange mantle (*Lime*).

3. A white powder.

(*a*) In B gives off H_2O.

(*b*) On platinum wire, or in forceps, lighted strongly, tinged the flame reddish, and did not melt (CaO).

(*c*) gave the S reaction.

(Substance is *Gypsum.*)

N.B.—Why try an evident "earth" for S. in the first instance?

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* Confirm by yellow-green p.c. of fragment in O.P. (*Barium*).

† When this is the case, the bead must be vesiculated or its contents boiled out, and transferred to a fresh one from an agate slab (Fig. 56) until a clear bead is obtained.

(*f*) Bead opaque with grey opaline matter (*much combined water*).

80, 192, &c., &c.

Gypsum.

Analysis by Bucholz.—SO_3 44·8, CaO 33·0, H_2O 21·0 = 98·8.

4. Powder in B. Acid O.P. (*a*) Intense, luminous, blue-green pyrochrome (*Copper*). (*b*) Black opaque balls: coppery matter from them after H.P. (*Copper*). (*c*) Green fragments, unchanged by H.P. (*Chromium*). N.B.—Only an experienced workman would suspect copper in presence of chromium in borax B.B.	**4.** A greenish-black powder. (*a*) Dissolved in borax gave a pure green colour; thought Cu was present, so knocked off the bead, and reduced it on C, when it was red from reduced copper. Got the Cu together, and redissolved the remainder of the bead in more borax, having first pressed it abroad. The reaction in the OF was yellow hot, and yellow-green cold, showing the presence of Cr_2O_3. (Substance was a mixture of CuO and Cr_2O_3.)
5. Powder in Boric Acid O.P. (*a*) Black opaque balls; violet after H.P. (*Cobalt*). (*b*) Brown transparent balls; colourless after H.P. (*Manganese.*) N.B.—*Very* doubtful if Mn could be suspected in presence of Co in borax.	**5.** A brownish-black powder. (*a*) Dissolved in borax gave a beautiful reddish-blue, showing the presence of CoO. The red colour, however, indicating the presence of another metal, tried it with soda and saltpetre on Pt. foil, and got the blue colour of Mn. (Substance was CoO and MnO_2).
6. Powder in B. Acid O.P. (*a*) Unattacked fragments.—As mineral is soft, try for SO_3 or P_2O_5 by— (*b*) Powder fused with soda on Al plate; boiled, dried, and— (*c*) Residue in B. Acid O.P. Great effervescence without smell, green p.c. unaltered (*Sulphuric Acid*).* (*d*). Transparent balls, evolving opaline matter by continued O.P. (*Barium*).†	**6.** A pinkish opaque mineral. (*a*) In B decrepitates, giving off little or no H_2O: changes to a grey colour. (*b*) In pt. forceps, melts and gives a green colour to the OF (pres. of BaO). (*c*) Gives no sublimate on C. (*d*) With soda on C, greatest part sinks in, but a portion of white *remains on the year rings* (*pres. of CaO*).‡ (*e*) The remains, dug out of the

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* Confirm by *black stain* on silver. (See Sulphur).

† Confirm by yellow-green p.c. of fragment in O.P. (*Barium*) and *Lime* by orange-red mantle p.c. in E.P.

‡ To detect *Lime* in No. 6.

N.B.—Most probably *Strontia* and *Iron* present here.

76, 77, 132, &c.

Barite.

Analysis by Heidingsfeld.—Ba SO_4 83·10, SrS_4O 7·10, $CaSO_4$ 6·12, Fe_2O_3 1·83 = 99·74.

C and put on a silver plate with H_2O, give reaction for sulphur.

(Mineral is *Barite* with trace of lime.)

7. Powder in B. Acid O.P.

(*a*) Great effervescence without yellowing green p.c., no smell (*Sulphuric Acid*).

(*b*) Bead opaque with grey opaline matter, requiring 4 changes (over 40 per cent. combined H_2O and little or no alkali which would remove opalescence).

(*c*) About two-sevenths white opaque fragments, affording immediate milkiness on addition of lime powder O.P. (about $\frac{2}{7}$ *Alumina*).

(*d*) Powder in Pink P. Acid P.P. all dissolved (no Silica).

36, 40, 45, &c.

Aluminite.

Analysis by Stromeyer. — SO_3 23·36, Al_2O_3 29·25, H_2O 46·37, = 100.

7. A white chalky mineral.

(*a*) In B gives off H_2O, which has an acid reaction. No decided reaction in the forceps: does not melt. No sublimate on C.

(*b*) With Co soln. in OF becomes blue (Al_2O_3).

(***With soda**, on C, **substance remains outside.****)

(*d*) The C dug out, wetted on ag. foil, gives S reaction.

(*e*) It is soluble in HCl.

(Substance is ***Aluminite.***)

N.B.—Why try "a white chalky mineral" on C? Any *Iron* would have destroyed the Co soln. reaction.

8. Powder in B. Acid O.P.

(*a*) Dissolves with great effervescence, fumes, and suffocating smell (an alkali, with chlorine or fluorine): green p.c. completely yellowed (over 5 per cent. of *Soda*).

(*b*) On addition of cobalt oxide O.P. all balls immediately dissolved, forming a bead, blue, cold (over 30 per cent. alkali).

(*c*) On addition of fresh powder with copper oxide O.P. no blue p.c. (no chlorine).

(*d*) Bead boiled with drop of water in glass bulb, makes its neck dull (*Fluorine*).

(*e*) Powder of a fused fragment, boiled and dried, in P.B. Acid O.P. about $\frac{1}{7}$ unattacked white fragments, which produce milkiness

8. A white compact mineral, like fossilized cocoanut "meat."

(*a*) Does not change in B, and gives off little H_2O.

(*b*) In the forceps melts easily to a round ball, colouring the OF reddish-yellow (soda).

(*c*) On C gives no sublimate, but melts to a clear bead, opaque when cold, which spreads out, and part sinks into the C.

(*d*) With Co solution becomes blue (Al_2O_3).

(*e*) No action for S on ag. foil: no action for CO_2 with A-Cl dil.: no action in B for Cl, Br, or I, so tried it with P salt in open tube, and got the Fl reaction: also tried it with HSO_4 in porcelain cup on glass, and got a first-rate reaction for Fl, so decide the substance to

* To detect *Alumina* in No. 7.

on addition of lime powder O.P. (about ½ *Alumina*, or *Al silicate*).

(*f*) A fragment fused on Al plate O.P. with water until the soda is dissolved and washed away, and the residue glows, affords a bright blue with Co solution and O.P. (*Alumina*, free from metallic oxides).

(*g*) Powder of (*e*) in pink P. Acid P.P. all dissolved (no silica).

85, 86.

Cryolite.

Analysis by Berzelius.—F 54·07, Al 13·00, Na 32·93 = 100.

be fluoride of sodium and aluminum, or *Cryolite.*

N.B.—Any *Iron* present would have destroyed the Co soln. reaction.

The fluorine is not suspected here, until after a series of tentative failures in search of other things.

9. Powder in B. Acid O.P.

(*a*) About ¾ blue-black fragments, affording a blue bead on large addition of P. Acid H.P. (about ¾ *Tungsten*); about ⅓ brown-black opaque balls, with rust-like matter (about ⅓ *Iron*): a few brown transparent balls, colourless after H.P. (a little *Manganese*).

(*b*) Powder in P. Acid H.P. an azure-blue bead (*Tungsten*), which changes to red on addition of soda O.P. (over 15 per cent. *Iron*).

8, 24, 72, &c.

Wolframite.

Analysis by Rammelsberg.—WO_3 75·56, FeO 20·17. MnO 3·54 = 99·27.

9. A black mineral, with metallic lustre.

(*a*) Is not magnetic before roasting, nor after. Decrepitates in B, but gives off no H_2O.

(*b*) Gives no sublimate on C, and no smell of SO_2 or As.

(*c*) With borax gives a reddish bead cold, as also with P salt.

(*d*) Is slightly soluble in HCl, and gives a blue colour with K_4FeCy_6 (Fe_2O_3).

(*e*) Heated with HSO_4 a blue fluid is obtained.

(*f*) Melts to a slag with soda, and is slightly fusible on the edges.

(Substance is *Wolframite.*)

10. Powder in B. Acid O.P.

(*a*) Great effervescence and white vapour with choking smell (*Chlorine* or *Fluorine*).

(*b*) On addition of copper oxide O.P., a blue p.c. (*Chlorine*).

(*c*) Fragment on C slip Al plate H.P. melts and affords a copious white sublimate, which, through a lens, appears as myriads of metallic balls (*Mercury*); these scraped together, form large shining visible globules.

(N.B.—Calomel, Hg Cl *sublimes at once.* Corrosive sublimate

10. A white crystalline substance.

(*a*) In B gives off a white vapour, which settles on the sides of the bulb, and turns yellow while hot. In the forceps gives off a lot of white smoke.

(*b*) On C is melted, and gives off copious white fumes, which settle on the C, and are very volatile.

(*c*) With soda in B, gives off a substance which settles on the side, and forms a mirror: when rubbed forms gobules (Hg).

(which this must have been) *fuses first*, and then sublimes.

(*d*) With CuO on C gives a beautiful blue flame, striped green (presence of Cl).

(The substance is, therefore, HgCl, or Cl_2.)

11. (See (9), with about ½ Manganese).

19, 45, &c.

Hübnerite.

N.B.—In (9) upwards of 3 c/c Manganese is missed by using borax, and not even detected by Soda afterwards.

11. A substance with metallic glance.

(*a*) In B gives no H_2O, and does not change. In forceps melts slightly on the edges. Gives no sublimate on C.

(*b*) In the OF in borax, gives the Mn reaction, and in RF, reactions for Fe.

(*c*) In P salt OF, gives the Fe reaction, as Mn does not colour the bead so strongly in P salt as in borax.

(*d*) In the RF got a red bead, which showed that either TiO_2 or WO_3 was there; but titanic Fe does not melt in the forceps: this did, so

(The mineral is *Manganese Wolfram.*)

12. Powder in B. Acid O.P.

(*a*) Great effervescence, with "smoke," and garlic smell and suffocating odour at the same time (*Arsenic Acid;* and, as proved by its blue p.c. with copper oxide O.P. *Chlorine*). Bead milk-white enamel-like, opaque (cannot be due to alumina and lime; so probably *Lead*).

(*b*) Fragment on Al plate O.P. fuses, with choking and garlic fumes, and copious yellow, brown, and white subt., first and last turning permanently brown in P.P. (large proportion of *Lead*).

(*c*) Grey, metallic malleable ball, with crystalline facets on cooling. (*Phosphate of Lead;* confirm by adding K carbonate, K pyrotungstate and potash to bead (*a*) H.P., when a turquoise-blue opaque bead shows *Phosphoric Acid*).

12. The substance is yellow, with a crystalline structure.

(*a*) In B decrepitates and changes colour a little, but gives off no H_2O.

(*b*) On C gives a smell of As, and smokes; which settles as a sublimate some distance off, while nearer the assay there is a yellow sublimate of PbO, and a globule of Pb is left behind.

(*c*) With CuO on C it shows a trace of Cl.

(Arsenate of lead, or *Mimetite.*)

N.B.—Here, probably, a considerable proportion of phosphoric acid is missed.

8, 72, 238, &c. *Mimetite.* *Analysis by Rammelsberg.*—Pb_3AsO_6 71·70, $Pb_3P_2O_6$ 19·00, Pb Cl 9·45 = 100·15.	
13. Powder in B. Acid O.P. (*a*) Great effervescence with "smoke," and choking smell; with CuO a sky-blue p.c. (*Chlorine*). (*b*) Dark blue p.c. from powder at bottom of bead, and enamel-like matter (*Lead*). (*c*) Fragment on Al plate O.P. Choking white fumes (large proportion of *Chlorine*), dark blue p.c. from assay (*Lead*): no subt. (no arsensic, &c.): with C slip, copious yellow, brown, and white subts. first and last turning brown in P.P. (large proportion of lead). 225, 226, 228, &c. *Cotunnite.* *Analysis by Covelli.*—Cl 25·5, Pb 74·5 = 100.	**13.** Substance is of a grey colour, with a glassy lustre. (*a*) In B it melts, giving off no H_2O. (*b*) On C melts, affording first a yellow sublimate of Pb, and outside a thick white one, which is pretty volatile. With $KO\bar{O}$, it is quickly reduced, leaving a globule of lead. (*c*) In B with soda gives no smell, and nothing is deposited on the tube. (*d*) In the open tube gives off a white sublimate, which, treated before the blowpipe, aggregates into drops of a white or grey colour; opaque. (*e*) With CuO gives a strong Cl reaction. (I therefore suppose the substance to be PbCl.)
14. Powder in B. Acid O.P. (*a*) Minute black opaque fragments; on addition of soda H.P. dissolves to green bead; lines in spect. Fig. 97. (*Pure Uranium Oxide*). N.B.—A large proportion of Iron, and other things, might have been present without detection by the borax assay.	**14.** The substance is an orange powder. (*a*) In B changes to a liver colour, and gives off H_2O. On C no sublimate, and with soda or $KO\bar{O}$, is not reduced to metal, but makes a sort of slag. (*b*) In OF in borax, is yellow when cold; in RF, yellow with green tinge. (*c*) In OF in P salt the bead is greenish-yellow; in RF emerald green. (*d*) The borax bead with zinc on C becomes green. (Substance is, therefore, oxide of *Uranium.*)
15. Powder in B. Acid O.P. (*a*) Slight ebullition and fumes, with choking smell; blue p.c. with CuO, and heated with drop	**15.** A green wax-like substance. (*a*) In B decrepitates, and gives off no H_2O.

of water in glass bulb, attacks the glass (*Chlorine and Fluorine*).

(*b*) A large transparent yellow ball (*Lime and Lead-phosphate*: no other substance with its high specific gravity—6 to 7—affording a ball here); on addition of K carbonate, K pyrotungstate and potash H.P. a blue bead (*Phosphoric Acid*).

(*c*) Fragment on Al plate O.P. fuses to a ball with crystalline facets on cooling (*Lead-phosphate*); with C slip and soda, a copious yellow, brown, and white subt.; first and last colours turning permanently brown in P.P. (*large proportion of Lead*); a comparatively large grey metallic squeezable ball (*large proportion of Lead*).

1, 24, 72, &c.

Pyromorphite, or *Polysphærite.*

Analysis of Polysphærite by Kersten.—$Pb_3P_2O_6$ 77·02, Pb Cl 10·84, CaF 1·09, $Ca_3P_2O_6$ 11·05 = 100.

16. Powder in B. Acid O.P.

(*a*) Nearly all yellow opaque fragments: blue after H.P., which afford an amethystine colour on large addition of P. Acid, H.P. (*nearly the whole, Titanium Oxide*): a very few brown-black opaque balls (*a very little Iron*).

85, 86, granite, &c.

Rutile.

Analysis by H. Rosé.—TiO_2 98·47, Fe_2O_3 1·53 = 100.

17. Paste on Al plate O.P.

(*a*) No sublimate: (no arsenic, &c.)

(*b*) With C slip, O.P. copious yellow, brown, and white subts., first and last becoming brown in P.P. (*large proportion of Lead*):

(*c*) dark blue p.c. from assay (*Lead*).

(*b*) In forceps melts easily, colouring the outer flame blue.

(*c*) On C melts to a white *crystalline* bead, and with $KO\bar{O}$ gives a bead of lead.

(*d*) Mixed with CuO in OF on C, gives a strong reaction for chlorine.

(Substance is *Pyromorphite.*)

N.B.—All the P_2O_5 apparently missed here, unless the expression "crystalline bead" refers to it. A lead mineral "melting easily" in platinum forceps indicates ruin to the latter!

16. A reddish mineral, with metallic glance.

(*a*) In B does not give off H_2O. and does not decrepitate. In forceps infusible.

(*b*) On C, gives no sublimate; with soda, melts to a reddish bead.

(*c*) In borax, in OF, gives the Fe reaction; and in RF the colour goes away, or nearly so.

(*d*) In P salt in OF gives a colourless bead; in RF, a beautiful violet colour.

(The mineral is *Rutile.*)

17. A yellow earthy-looking substance. (High specific gravity.)

(*a*) In B changes colour a little; on C got a sublimate of Pb; the assay melted, and there was trace of a lighter sublimate in the distance.

(*b*) To see what was with the

(*d*) Powder of the crushed residue—after volatilisation of lead—in B. Acid O.P.: green fragments, unchanged by H.P., and dissolving to a green bead (pink hot) on addition of soda O.P. (*Chromium.*)

85, 86, granite, &c.

Crocoisite.

Analysis by Pfaff.—CrO_3 31·75, PbO 67·91 = 99·64.

lead, added a little borax glass to the slag left on the C, and treated to OF, when a green bead was produced. This could only be Cr_2O_3 or VO_3. To prove which it was, treated some of the original ore to OF in P salt, when it was coloured green.

(Substance is *Crocoisite.*).

18. Powder in B. Acid O.P.

(*a*) Large black fragments, with yellowish matter round them (*probably Tungsten or Molybdenum*): on addition of lime-powder, O.P., balls, coloured dark brown after H.P. (*Molybdenum*).

(*b*) Paste on C slip, Al plate, O.P., a copious pale straw-yellow subt., turning dark blue when touched for a second by H.P. (*large proportion of Molybdenum*).

(*c*) Subt. of (*b*), scraped off, in P. Acid, O.P., with small quantity a blue bead; with more, bluish green (*Molybdenum*).

8, 24, 72, &c.

Molybdite.

Chem. Comp. Mo 65·71, O 34·29 = 100.

N.B.—Ought to be no lead here.

18. A yellow earthy substance.

(*a*) In B decrepitates forcibly; gives off H_2O. On C got no sublimate but that of Pb with a few metallic beads of lead.

(*b*) Then tried it with borax glass, when I got a dirty colour, so tried it in a bead of borax, and reduced it on C, when a black bead was produced with some white in it from the lead oxide, which spoke of the presence of MO_3.

(*c*) To prove this, dissolved some of the powder in P salt, and got in the OF a green colour, which with the other reaction proved the presence of MO_3.

(*d*) Then dissolved some of the mineral in $KHSO_4$ diluted with H_2O, and then added a piece of zinc, when I got a blue colour from the formation of a lower oxide of the MO_3.

(The substance is *Molybdan-ochre.*)

19. Powder in B. Acid O.P.

(*a*) About nine-tenths white fragments, unaltered by H.P.; unaltered by calcium borate (not Al, and probably, on account of its great specific gravity—6 to 7—*Tin*): one or two small brown fragments (*trace of Tantalum*): one or two brown opaque balls, with rusty matter (*trace of Iron*): one or two brown transparent balls, colourless after H.P. (*trace of Manganese*).

(*b*) Fragment on Al plate O.P., metallic sweat without subt.

19. A brown mineral with metallic, or rather resinous, glance.

(*a*) In B decrepitates feebly; gives off no H_2O.

(*b*) On C gives a white sublimate which is not volatile, and which, with Co solution, gives a bluish-green colour. In the forceps it does not melt; but a white efflorescence comes out upon it.

(*c*) In OF with soda melts to a slag: but in RF with $KO\bar{O}$ got a bead of white metal which was malleable.

(The substance is *Cassiterite.*)

(*Tin*) : white efflorescence on assay in cooling (*Tin*) : with C slip, soda, and K cyanide : a whitish, metallic, squeezable ball (*large proportion of Tin*).

8, 34, 72, 238, &c.

Cassiterite.

Analysis by Berzelius.—SnO_2 93·6 ; TaO_5 2·4, Fe_2O_3 1·4, MnO_2 0·8 = 98·2.

N.B.—Here traces of Tantalum, Iron, and Manganese were probably missed.

20. Powder in B. Acid, O.P.

(*a*) About nine-tenths, small, transparent, colourless, sago-like balls, surrounded by semi-transparent viscid matter (*about nine-tenths Zinc*) : a few brown transparent balls, colourless after H.P. (*a little Manganese*) : one or two brown-black opaque balls with rust-like matter (*trace of Iron*).

115, 108, 112, &c.

Zincite.

Analysis by Hayes.—ZnO 93·48, MnO 5·50, Fe_2O_3 0·80 = 99·78.

20. A reddish mineral, with resinous glance.

(*a*) In B does not decrepitate. On C gives a sublimate which is green on moistening with Co solution.

(*b*) In forceps infusible. With P salt and borax gave a manganese reaction.

(The substance is *Red Oxide of Zinc.*)

21. Paste on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*) : O.P. without fusing : a considerable snow-white efflorescence over assay on cooling (*considerable proportion of Tin*) : a slight white sublimate, yellow hot ; affording sago-like balls in B. Acid, O.P. (*a little Zinc*) :

(*b*) With K carbonate, in candle P.P., after volatilisation of all the sulphur, a pink-tinged opaque bead (*considerable Iron*) : with strong H.P.—still on bare plate—copper-red oxide, and a bronze metallic ball (*considerable proportion of Copper*). Confirmed by luminous blue-green p.c. in B. acid.

8, 24, 72, 238, &c.

Stannite.

Analysis by Rammelsberg.—S 29·05, Sn 25·65, Cu 29·38, Fe 6·24, Zn 9·68 = 100.

21. A dull grey semi-metallic-looking mineral. (High Sp. Gr.)

(*a*) In B gives off S, which settles on the tube. In open tube, S burns over the assay ; also a white sublimate, which settles on the tube.

(*b*) On C, I got a thick white sublimate which settled close round the assay, and on being wetted with Co solution gave a blue-green colour ; so there is evidently Sn present. There was no sublimate farther off from the assay.

(*c*) In borax the white oxide was slowly dissolved to a colourless bead, which was unchanged in the RF on C. In P salt melted slowly to a clear bead, so I only found S and Sn.

(The mineral is *Stannite.*)

N.B.—Large proportion of Copper missed here !

22. Paste on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*) O.P., a yellowish-red subt. which whitens in P.P., but affords a black spot to O.P. (*Antimony Sulphide*): a copious white subt., instantly blackened by O.P. (*large proportion of Antimony*): with C slip, O.P., copious yellow, brown, and white subts., first and last turning brown in P.P. (*large proportion of Lead*); on addition of soda, H.P., a red, metallic, squeezable ball (*considerable proportion of Copper*).

8, 24, 72, 238, &c.

Bournonite.

Analysis by H. Rosé.—S 20·31, Sb 26·28, Pb 40·84, Cu 12·65 = 100·08.

22. A grey mineral, with metallic glance.

(*a*) In the B got nothing particular. In open tube a strong smell of So_2, with a sublimate of Sb, and some grey drops.

(*b*) On C got first a sublimate of Sb, then one of Pb, and finally a bead of Cu was left. Did not perceive a smell of As, nor had any colour in the tube to indicate its presence. Thus S, Sb, Pb, and Cu are present.

(The mineral is *Bournonite.*)

23. Fragment on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*); O.P., a copious white subt., volatilising in H.P. with garlic smell (*large proportion of Arsenic*); with C slip, no further subt. (no other volatile metal).

(*b*) After roasting on bare plate, till S and As have been volatilised, the residue crushed, and powder in B. Acid O.P., the whole, brown-black opaque balls, with rust-like matter (*the whole residue Iron*).

8, 24, 72, 238, &c.

Mispickel.

Analysis by Stromeyer. — As 42·88, S 21·08, Fe 36·04 = 100.

23. A greyish-white mineral, with metallic glance.

(*a*) In B gives off a red sublimate with smell of As (AsS), then a mirror of As. In open tube gives off SO_2 and forms a sublimate of As and S.

(*b*) On C melts to a bead, giving off As and S. The bead is magnetic and has a rough surface.

(*c*) The roasted mineral in P salt and borax gives the Fe reaction, and nothing else.

(Must be *Mispickel.*)

24. Probably common

46, 105, 72, &c.

Pyrite;

analysis same as above, *minus* the arsenic.

24. A mineral from Pampelli, Corsica.

(*a*) In B gives off S. On C melts to a magnetic ball, giving off fumes of So_2. In forceps, is with difficulty melted on the edges.

(*b*) Is slightly magnetic before roasting.

25. Powder in B. Acid O.P.

(*a*) Large number of brown transparent balls, colourless in H.P. (*large proportion of Manganese*): considerable number of opaque black balls, violet after H.P. (*considerable proportion of Cobalt*): some brown-black opaque balls, with rust-like matter (*a little Iron*): luminous blue-green p.c. with a few blue-black opaque balls; coppery suffusion after H.P. (*a little Copper*). N.B.—The above must be boiled out of the first bead in consequence of the large quantity of opaque grey matter formed (*chemical water*), and applied to a second bead, O.P.

51, 72, 24, &c.

Wad.

Analysis by Rammelsberg.—MnO 40·05, 09·47, Fe_2O_3 4·56, CoO 19·45, CuO 4·35, H_2O 21·24, K_2O 0·37 = 99·94.

26. Fragment on Al plate, momentary O.P.

(*a*) No smell of SO_2 (no sulphur): minute metallic sweat (*trace of Bismuth*): O.P., faint white subt. volatilising in H.P. with garlic smell (*trace of Arsenic*): with C slip O.P., a little yellow and white subt. turning brown in P.P. (*a little Lead*).

(*b*) The residue, after roasting, crushed to fine powder, in B. Acid O.P., nearly four-fifths (of original powder) minute black fragments; affording on addition of soda O.P. a yellow bead, green after H.P., and thick absorption

(*c*) In borax and P salt got only the Fe reaction.

(*d*) The mineral does not appear to be a magnetic pyrites, for that gives off H_2S with HCl, and this does not, but it may be a combination of a magnetic oxide with some sulphide.

25. A black rotten-looking powder.

(*a*) In B decrepitates, and yields H_2O. In forceps does not melt.

(*b*) In borax, OF, got a red-violet colour which was not pure, so supposed Mn was there. In the RF, the Mn colour left, and a beautiful blue remained alone.

(*c*) Tried them with soda and saltpetre on Pt. foil, and got Mn reaction. Then with soda on C got a slight trace of S.

(The substance, therefore, is *Erd Cobalt.*)

N.B.—Only a very practised "hand" would detect Mn in presence of Co in borax. Cu and Fe appear to have been missed here.

26. A black mineral, with submetallic glance.

(*a*) Very difficultly melted in forceps. In B gives a sublimate of S. On C does not change or give a sublimate.

(*b*) In borax, OF, is dissolved with difficulty, and gives an Fe reaction. In RF also an Fe reaction. In P salt, got in OF a yellowish-green coloured bead, which changes in RF to a beautiful emerald green. This tells us it is Uranium, and there is only one mineral of this nature—*Uranpecherz.*

N.B.—It seems rather a strainbands at D, Eb, and F—see Fig. 97—(*nearly four-fifths Uranium*): very few brown-black opaque balls with rust-like matter (*a very little Iron*); very few transparent balls, opaque hot, pale green cold (*a very little Lime, with trace of Magnesia, containing Iron protoxide*).

(*c*) Powder in pink P. Acid P.P. all dissolved but a few spiculæ (*a little Silica*): bead a mixture of green and pink (*no Alkali or Alumina*).

8, 24, 72, &c.

Uraninite.

Analysis by Rammelsberg.—UO, U_2O_3 79·15, FeO 3·90, CaO 2·81, MgO 0·46, SiO_2 5·30, Pb 6·20, As 1·12, Bi 0·65, H_2O 0·36 = 99·61.

ing of the term to call this a "Blowpipe Analysis." Many minerals would have afforded reactions for Iron and Uranium; the only two procured here.

27. Fragment on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*): O.P., no subt. (no arsenic, &c.): with C slip O.P., no subt. (no volatile metal):

(*b*) Roasted powder in B. Acid O.P., the whole residue—about three-fifths of original powder—brown transparent balls, colourless after H.P. (*about three-fifths Manganese; therefore, nearly two-fifths Sulphur*).

(Quartz veins)

Alabandite.

Analysis by Arfvedson.—S 37·9, Mn 62·1 = 100.

27. A black vitreous mineral. (High Sp. Gr.)

(*a*) In B a very small sublimate of S. In open tube got a lot of SO_2.

(*b*) On C gave no reaction alone, but after roasting, the remainder dissolved in borax gave a red-violet bead. This colour vanished in the RF, so there was nothing there but Mn. There are two Mn minerals combined with S, MnS, and MnS_2, but the latter gives off more S, and has a *red* streak on porcelain, whereas this has a *green* one.

(The mineral is *Manganblende.*)

28. Powder in B. Acid O.P.

(*a*) Slight fumes with smell of SO_2 (*Sulphur*): no garlic smell (no arsenic): after gentle roasting to eliminate the S, about three-fifths original powder, small, transparent, colourless, sago-like balls, surrounded by semi-transparent viscid matter (*about three-fifths Zinc*): one or two larger transparent balls, emitting woolly matter turning reddish after H.P.

28. A mineral, with resinous glance.

(*a*) In B decrepitates, and gives off some As as suboxide. In open tube gives fumes of AsO_3 and SO_2, which redden litmus paper.

(*b*) On C, OF, gives a white sublimate which is yellow while hot, and with Co solution turns green.

(*c*) In borax gives an Fe reaction; in P salt ditto. So we (*a very little Cadmium*): very few brown-black opaque balls with rust-like matter (*a very little Iron*).

55, 136, &c.

Sphalerite.

Analysis by Löwe.—S 33·15, Zn 61·40, Fe 2·29, Cd 1·50 = 98·34.

29. Fragment on Al plate, momentary O.P.

(*a*) Smell of SO$_2$ (*Sulphur*); O.P. a yellowish red subt., which whitens in P.P., but affords a black spot to O.P. (*Antimony Sulphide*): a copious white subt. instantly blackened by O.P. (*large proportion of Antimony*):

(*b*) Residue after elimination of the Sb, powdered, in B.Acid O.P., about one-eighth original powder brown-black, opaque balls, with rust-like matter (*about one-eighth Iron*).

204, 215, 220, &c.

Berthierite.

Analysis by Pettko.—S 29·27, Sb 57·88, Fe 12·85 = 100.

30. Fragment on Al plate momentary O.P.

(*a*) Smell of SO$_2$ (*Sulphur*): O.P. a faint, fixed, white subt., which, scraped off, affords in B. Acid O.P. sago-like minute transparent balls, in semi-transparent viscid matter (*a very little Zinc*): with C slip, O.P., a copious white subt., instantly blackening in O.P. (*a considerable proportion of Antimony*): a few streaks of rose-coloured sublimate below the white (*trace of Silver*): with K carbonate on the bare plate, candle P.P., a pink-tinged mass (*a little Iron*): the mass on C slip H.P., a comparatively large, red, metallic, squeezable ball (*large proportion of Copper*).

24, 72, 238, granite, &c.

Tetrahedrite.

Analysis by Bruno Kerl.—S 25·82, Sb 28·78, Cu 37·95, Fe 2·24, Zn 2·52, Ag 0·67 = 97·98.

found Fe, Zn, S, and As. (*Zinc Blende.*)

29. A bluish-black mineral; metallic lustre.

(*a*) In B got a cherry red sublimate of sulphide of Sb. In open tube SO$_2$ and SbO.

(*b*) On C, SbO goes off, and an unmelted mass was left behind with a slight smell of H$_2$S. This mass pounded and tried in borax, gave an Fe reaction.

(The mineral is, therefore, *Berthierite.*)

30. A steel grey mineral, with metallic lustre.

(*a*) In B got sublimates of SbS and AsS; in the open tube, of SbO, SO$_2$, and AsO$_3$.

(*b*) On C got a sublimate of Sb, some distance from the assay, and nearer, a sublimate of Zn, moved by Co solution. The As goes off first, then the Sb, then the Zn.

(*c*) The bead that remained after the Zn had gone off was ground up and roasted, as S is still left in it; the roasting, of course, on charcoal.

(*d*) I then treated in borax, and found the bead coloured green-blue. Knocked off the bead, and reduced on C (without Sn, must blow at least ten minutes). The Cu is then reduced as metal, and falls to the bottom; if nothing more is there, the bead will then be colourless.

(The mineral is *Fahlerz*).

31. Fragment on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*): copious white subt., volatilising in H.P. with garlic smell (*large proportion of Arsenic*); with C slip no further subt. (no other volatile metal).

(*b*) After volatilisation of S and As, crushed residue in B. Acid O.P., about one-fourth original powder, black opaque balls, violet after H.P. (*about one-fourth Cobalt*): a few brown-black opaque balls, with rust-like matter (*a little Iron*).

8, 238, 24, 72.

Cobaltite.

Analysis by Stromeyer.—S 20·08, As 43·46, Co 23·10, Fe 3·23 = 99·87.

31. A grey mineral, metallic glance.

(*a*) In B gave off S, no As. In open tube SO_2 and AsO_3.

(*b*) On C fuses to a bead, dark grey, giving off fumes of SO_2 and AsO_3.

(*c*) In borax gives Co reaction; tried it on C with borax glass for some time, but could not reduce the Co to get a Ni reaction; so think the mineral is

(CoAs, CoS_2, or *Cobaltine.*)

N.B.—Curious that 43 c/c of As should have been missed here, in G.B.

32. *Spaniolite* or *Mercuriferous Tetrahedrite.* (See No. 30, *plus* Hg 1 to 17 per cent.)

N.B.—The appearance of the mineral must have helped him to form the rather sudden conclusion arrived at.

32. A black mineral, with metallic glance.

(*a*) In B decrepitates, and gives a black sublimate, which may be suboxide of As or HgS. In open tube got a sublimate of Sb, and a ring of Hg; got also SO_2 and a strong smell of As. The metallic ring shows that the black oxide in the shut tube was formed by Hg, for no other substance would give a ring of metal in the open tube.

(Proceeded no further, but the mineral is evidently *Spaniolite*).

33. Paste on Al plate momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*): O.P. a white subt., yellowish over black in the centre; the black whitening, the white instantly blackening in O.P. (*considerable proportion of Antimony*); with C slip O.P., magnificently coloured, crimson splashes in the above white subt., unchanged by P.P. (*large proportion of Silver*): with K carbonate and candle P.P., after the S has been eliminated by P.P. on the

33. An iron black mineral, with metallic lustre.

(*a*) In B nothing particular. In open tube, smell of SO_2, and a large deposit of SbO_3.

(*b*) On C a trace of AsO_3, and a sublimate of SbO_3, which was coloured red—brownish near the assay—and a large "korn" of Ag remained behind. Thus we had S, As, Sb, and Ag; so that the mineral can either be dark *Pyrargyrite*, or *Melanglanz*. To find the difference, try the streak on bare plate, a pink-tinged bead (*trace of Iron*): with pure blue H.P. covering the assay, a proportionately large, pure white, metallic ball (*very large proportion of Silver*).

84, 72, 8, 238, &c.

Stephanite.

Analysis by Bruno Kerl.—S 16·51, Sb 15·79, Ag 68·38, FeO 0·14 = 100·12.

porcelain; the former gives a red streak, the latter a black one.

(*Melanglanz.*)

N.B.—The idea of referring *from* the analysis *to* the streak of a mineral is worthy of * * *, but not of Mr. H.

34. Paste on Al plate (on account of metallic lustre, specific gravity, &c.), momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*): metallic sweat (*Bismuth*): O.P., white subt. volatilising in H.P. with garlic smell (*Arsenic*): white subt. instantly blackening in O.P. (*Antimony*): with C slip, O.P., yellow and white subt., only darkening temporarily in P.P., and scraped off, giving brown streaks to B. Acid O.P. (*Bismuth*).

(*b*) Residue after roasting in P.P., powdered, in B. Acid O.P. black opaque balls, violet after H.P. (*Cobalt*): luminous blue-green p.c., and blue black opaque balls with coppery suffusion after H.P. (*Copper*): green fragments, with white metallic lustre after H.P. (*Nickel.*)

34. A dark grey metallic powder. (High Sp. Gr.)

(*a*) In B nothing notable. In open tube, got SO_3, As, and trace Sb.

(*b*) On C a strong smell with fumes of As, and a sublimate of Bi and Sb.

(*c*) On C with borax glass, got first a strong colour of Co, then, after long blowing, a reaction for Ni.

(*d*) With P salt a weak reaction for Cu. So in this mixture there is

(S, As, Sb, Bi, Co, Ni, and Cu.)

N.B.—Query. How much loss of time and patience does "long blowing" indicate?

35. Filings in B. Acid O.P.

(*a*) Instantaneous, luminous, blue-green p.c., with blue-black opaque balls, having a coppery suffusion after H.P. (*Copper*): small, transparent, sago-like balls, in semi-transparent viscid matter (*Zinc*): brown-black opaque balls, with rust-like matter (*Iron*): green fragments with white metallic lustre after H.P. (*Nickel*).

N.B.—Instead of "a trace," there is 40 per cent. of Nickel in Argentine.

35. An alloy.

(*a*) On C got a very strong deposit of ZnO, and the metal melted with difficulty to a bead which was rough on the surface.

(*b*) In borax glass, got an Fe reaction, or only a trace of what might be NiO.

(*c*) In P salt had a strong reaction for Cu, so I found only Cu, Fe, and Zn; but the bead of P salt was in OF coloured green, from the yellow of NiO combined with the blue of CuO, so judge the alloy to be

(*Argentine*, or *German Silver.*)

36. Fragment on Al plate O.P. (*a*) A considerable white subt. which, scraped off, affords small, sago-like, transparent balls in B. Acid O.P. (*considerable proportion of Zinc*): (*b*) Powdered residue after roasting, in B. Acid O.P., about two-thirds brown-black opaque balls with rust-like matter (about two-thirds original powder, *Iron*): about one-sixth brown transparent balls, colourless after H.P. (*about one-sixth Manganese*): 8, 24, 72, 238, &c. *Franklinite.* *Analysis by Berthier.*—Fe_2O_3 66·0, Mn_2O_3 16·0, ZnO 17·0 = 99·0.	**36.** A black mineral, with metallic glance. (*a*) Infusible. Is magnetic after roasting in RF. Dissolves with difficulty in HCl with smell of Cl. (*b*) In borax gives Mn and Fe reactions. In P salt the same. (*c*) On Pt. foil with saltpetre and soda, gives a strong Mn reaction. (*d*) With soda on C in RF, gives a faint reaction for Zn, so the mineral must be (*Franklinite.*)
37. Powder in B. Acid O.P. (*a*) Fumes, with choking smell, giving sky-blue p.c. on addition of CuO O.P. (*large proportion of Chlorine*): the black, opaque, copper oxide balls are partly dissolved, showing presence of much alkali, which, as the normal green p.c. is unchanged, must be (*Potassium*). Confirmed by violet p c. of powder in O.P.	**37.** A white crystalline salt. (*a*) In B gives off H_2O, decrepitates and melts; with $KHSO_4$ gives a strong smell of Cl. On Pt. wire colours the flame violet (KO). (*b*) A crystal moistened with HSO_4 gives the orange-yellow tinge and peculiar smell of chlorates. (The substance is, therefore, $KClO_3$.)
38. (See Analysis No. 22.)	**38.** A black-grey mineral, with metallic glance. (*a*) Gives a strong antimonial smoke, which smells a little of As. (*b*) Dissolved in HNO_3 and then found S separate, and on diluting the solution with H_2O, got a precipitate of SbO. On separating this, with HSO_4 got a precipitate of $PbSO_4$, and finally with ammonia, the blue of Cu. (The mineral is, therefore, *Bournonite.*)
39. (See Analysis No. 21.) N.B.—Mr. H. is more fortunate in detecting the Copper this time, in No. 39, than he was in No. 31.	**39.** A dark grey mineral, with semi-metallic glance. (*a*) In B with good heat, got a sublimate of S and nothing else. In open tube a smell of SO_2. (*b*) On C melted to a bead

40. Fragment on Al plate, momentary O.P.

(*a*) Smell of SO_2 (*Sulphur*): O.P., a copious white subt. volatilising in H.P. with garlic smell (*large proportion of Arsenic*); when the greater part of the As has been eliminated by O.P., and P.P. applied, an apple-green, capillary oxide over the whole assay (*large proportion of Nickel*): a slight white subt., which turns instantly black in O.P. (*a little Antimony*).

(*b*) Powdered residue in B. Acid O.P., almost all green fragments with metallic lustre after H.P. (*almost all the residue Nickel*): one or two black opaque balls, violet after H.P. (*trace of Cobalt*).

8, 24, 72, 238, &c.

Niccolite.

Analysis by Berthier.—As 48·80, Ni 39·94, Co 0·16, Sb 8·00, S 2·00 = 98·90.

pretty easily, giving a white sublimate of SnO_2.

(*c*) Roasted and tried in borax, gives a reaction for Fe.

(*d*) In P salt, RF, with tin, got Cu_2O.

(*e*) With soda and borax, got a bead of imperfectly malleable copper.

(The mineral is *Stannite.*)

40. A pale reddish mineral, with metallic glance.

(*a*) In B gives off As and forms a mirror. In the open tube AsO_3 in large quantities. On C melts to a grey bead and gives off lots of AsO_3.

(*b*) In borax, a reaction for Co. Could not see any for Fe, but after a few times treating got the Ni reaction.

(*c*) Tried for Cu with P salt, but got no reaction. Thus As, Co, and Ni, were found; lots of As, a trace of Co, and much Ni.

(The mineral is, therefore, *Niccolite.*)

N.B.—Here we have 0·16 of Cobalt obscuring for a considerable time the reactions of 40 c/c of nickel in borax.

To detect Phosphoric Acid.

41. Apple-green crystal from Spain.

(*a*) Powder unattacked in B. Acid O.P. As mineral is soft, try for SO_3 or P_2O_5.

(*b*) Powder fused with Soda on Al plate, boiled, dried, and treated in B. Acid O.P., no effervescence (no SO_3). White opaque balls unclarified by strong O.P. (not Magnesia; and therefore *Calcium Phosphate*).

(*c*) Balls of (*b*) just dissolved by adding specks of K Carbonate O.P., and K Pyrotungstate largely added in H.P., a turquoise blue, opaque bead on cooling (large proportion of *Phosphoric Acid*). Mineral is *Apatite*, and as it generally contains Cl and F—

(*d*) Powder with CuO in P. Acid O.P., an azure-blue p.c. (*Chlorine*); and the bead unrolled from the wire and heated in G.B. with a drop of H_2O, the neck of the glass is dulled (*Fluorine*).

Analysis of Apatite.—CaO 50, P_2O_5 42·26, Ca 3·97, F 3·77 = 101·00.

*To detect Boric Acid.**

42. A brownish black mineral (fragment).

(*a*) Powder in P Acid, coloured violet with Titanic Acid by H.P., on charcoal to prevent loss of volatile constituents, dissolved nearly to saturation, but leaving a clear bead.

(*b*) Made a bead of Sodium Pyrotitanate by fusing Titanic Acid with Soda on Al plate O.P. until all effervescence ceased.

(*c*) Fused (*a*) and (*b*) beads together, on C slip, Al plate, and added some drops H_2O; the mass crystallised a pale but very distinct blue colour (3 to 8 c/c *Boric Acid*). The mineral was ***Tourmaline:*** the blue reaction (Titanium borate) depends on the well-known facts that TiO_2 "affords in borax R.F. an enamel blue by flaming," and "in P. salt a fine violet colour." (Plattner).

Table XV.—Of some decrepitating† Minerals.

1. Anglesite.
2. Aragonite.
3. Barite.
4. Boulangerite.
5. Bournonite.
6. Calamine.
7. Caleïte.
8. Celestite.
9. Chalcophyllite.
10. Cheneviscite.
11. Chrysocolla.
12. Clausthalite.
13. Conicalcite.
14. Diallogite.
15. Diaspore.
16. Erynite.
17. Eulytite.
18. Evansite.
19. Fluor spar.
20. Galena.
21. Mendipite.
22. Miargyrite.
23. Plumbogummite.
24. Polycrase.
25. Pseudo-malachite.
26. Samarskite.
27. Spaniolite.
28. Sphalerite.
29. Stephanite.
30. Stolgite.
31. Triphyllite.
32. Turgite.
33. Turquoise.
34. Tyrolite.
35. Vanadinite.
36. Wulfenite.
37. Zorgite.

The above Minerals are to be powdered between agates and made into paste with a drop of water, before being treated B.B. on Al plate or Pt wire.

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* See *The Chemical News,* xlvii., No. 1221, page 186, for the *rationale* of these reactions.

† Latin *crepitatus,* participle of *crepito,* I crackle.

Table XVI.—Quantitative Arrangement of Silicates, with Types.

(N.B.—Important Bases in larger ratio, on the left hand.)

A.

1. *Álumínic silicates.* (*a*) Andalusite; (*b*) Chiastolite; (*c*) Sillimanite; (*d*) Cyanite; (*e*) Disthene.
2. *Álubórisódic silicates.* (*a*) Oural Tourmalines.
3. *Álucálcic silicates.* (*a*) Meionite; (*b*) Ekebergite; (*c*) Scapolite; (*d*) Couzeranite; (*e*) Scolexerose; (*f*) Atheriastite; (*g*) Zoisite; (*h*) Saussurite; (*i*) Anorthite.
4. *Álucálciférribóric silicates.* (*a*) Axinite.
5. *Álucálcisódic silicates.* (*a*) Nepheline; (*b*) Elæolite; (*c*) Labradorite; (*d*) Lemanite; (*e*) Andesine.
6. *Áluférric silicates.* (*a*) Staurotide.
7. *Áluférrimagnésic silicates.* (*a*) Gigantolite; (*b*) Iberite; (*c*) Fahlunite; (*d*) Weissite.
8. *Álufluóric silicate.* (*a*) Topaz.
9. *Áluglucínic silicates.* (*a*) Emerald; (*b*) Euclase.
10. *Álulíthic silicates.* (*a*) Triphane; (*b*) Petalite.
11. *Álumagnésic silicates.* (*a*) Lindsayite; (*b*) Sapphirin.
12. *Álumágnebóric silicates.* (*a*) Carinthian Tourmalines.
13. *Álumágnecálciférric silicates.* (*a*) Clintonite.
14. *Álumágneférric silicates.* (*a*) Pyrope; (*b*) Cordierite; (*c*) Polychroite; (*d*) Aspasiolite; (*e*) Chlorophyllite; (*f*) Bonsdorffité; (*g*) Esmarkite; (*h*) Praseolite.
15. *Álumangánic silicate.* (*a*) Carphalite.
16. *Álupotássic silicates.* (*a*) Orthose; (*b*) Ceylon moonstone; adularia.
17. *Álupotássiférric silicates.* (*a*) Retinite; (*b*) Pinite.
18. *Álupotássiflúolíthic silicates.* (*a*) Lepidolite.
19. *Álupotássisódic silicates.* (*a*) Gneiss; (*b*) Lyenite.
20. *Álupotássisódiférric silicates.* (*a*) Perlite.
21. *Álusódicálcic silicates.* (*a*) Cancrinite.
22. *Álusódicalcisulphúric silicates.* (*a*) Outremer.
23. *Álusôdichlóric silicates.* (*a*) Sodalite.
24. *Álusódisulphúric silicates.* (*a*) Noseane.
25. *Álusúlphicálcic silicates.* (*a*) Haüyne.
26. *Alúmisódic silicates.* (*a*) Albite.

C.

1. *Cálcic silicates.* (*a*) Wollastonite.
2. *Cálciálumínic silicates.* (*a*) Gehlenite: (*b*) Humboldtilite; (*c*) Grossularite.

3. *Cálciálumágneférric silicates.* (*a*) Idocrase.
4. *Cálcibóric silicates.* (*a*) Danburite; (*b*) Datholite.
5. *Cálcichrómic silicates.* (*a*) Ouvarovite.
6. *Cálciférric silicates.* (*a*) Hedenbergite; (*b*) Melanite.
7. *Cálciférralumínic silicates.* (*a*) Epidote; (*b*) Colophonite.
8. *Cálciglúcifluóric silicates.* (*a*) Melinophane.
9. *Cálciglúcisódic silicates.* (*a*) Leucophane.
10. *Cálcimagnésic silicates.* (*a*) Diopside; (*b*) Diallage.
11. *Cálcimágnálumínic silicate.* (*a*) Ædelforsite.
12. *Cálcimágnálusódiférrimangánic silicate.* (*a*) Violane.
13. *Cálcimágneférrálumínic silicates.* (*a*) Bronzite; Paulite; Augite; Hypersthene.
14. *Cálcimangánic silicates.* (*a*) Jeffersonite.
15. *Cálcisódic silicate.* (*a*) Pectalite.
16. *Cálcititánic silicate.* (*a*) Sphene.
17. *Cálcizirconióbic silicate.* (*a*) Wöhlerite.
18. *Cérálufèrricálcic silicates.* (*a*) Allanite; (*b*) Orthite.
19. *Cérilánthánic silicates.* (*a*) Cerite; (*b*) Tritomite.
20. *Cérilánthánicálcititánic silicate.* (*a*) Mosandrite.

F.

1. *Férric silicates.* (*a*) Anthosiderite.
2. *Férrálumínic silicates.* (*a*) Almandine.
3. *Férrálusulphúric silicates.* (*a*) Fayalite.
4. *Férricálcic silicates.* (*a*) Babingtonite; (*b*) Ilvaïte.
5. *Férricálciálumínic silicate.* (*a*) Hudsonite.
6. *Férricálcimagnálumínic silicate.* (*a*) Ouralite; (*b*) Hornblende.
7. *Férricérálucálcic silicates.* (*a*) Cerine.
8. *Férrimágnesálumínic silicate.* (*a*) Gedrite.
9. *Férrisódic silicates.* (*a*) Achmite; (*b*) Arfvedsonite.
10. *Férrisódicálcic silicates.* (*a*) Œgyrine.

G.

1. *Glucínic silicate.* (*a*) Phenacite.

H.

1. *Hýdric silicates.* (*a*) Opal; (*b*) Hydrophane; (*c*) Tabasheer.

1*a*. *Hýdrálumínic silicates.* (*a*) Pyrophyllite; (*b*) Pholerite; (*c*) Halloysite; (*d*) Allophane; (*e*) Tuesite; (*f*) Sèvres clay; (*g*) Mountain soap; (*h*) Smectite; (*i*) Sinope bol; (*j*) Meerschaluminite.

2. *Hydrálubarýtic silicates.* (*a*) Harmotome.
3. *Hydrálucálcic silicates.* (*a*) Thomsonite; (*b*) Mesole; (*c*) Gismondine; (*d*) Margarite.

4. *Hydrálucálcipotássic silicates.* (*a*) Phillipsite; (*b*) Christianite; (*c*) Chabasie.
5. *Hydrálucálcisódic silicates.* (*a*) Mesolite; (*b*) Faujasite.
6. *Hydráluférrimagnésic silicates.* (*a*) Chloritoid; (*b*) Masonite.
7. *Hydrálumagnésic silicates.* (*a*) Saponite.
8. *Hydrálumagnésicálcic silicates.* (*a*) Hornblende.
9. *Hydrálupotássic silicates.* (*a*) Agalmatolite.
10. *Hýdrálupotássimagnésic silicates.* (*a*) Giesceckite.
11. *Hydrálusódic silicates.* (*a*) Natrolite; Mesotype; (*b*) Analcime.
12. *Hýdrocálcic silicates.* (*a*) Okenite.
13. *Hýdrocálcialumínic silicates.* (*a*) Prehnite.
14. *Hýdrocálcipotássic silicates.* (*a*) Apophyllite.
15. *Hýdrocárbocériférric silicates.* (*a*) Pyrorthite.
16. *Hýdrocúpric silicates.* (*a*) Dioptase; (*b*) Chrysocole; (*c*) Dillenburgite.
17. *Hýdroférric silicates.* (*a*) Hisingerite.
18. *Hýdroférralumínic silicates.* (*a*) Rhodalite; (*b*) Nontronite; Glauconite; (*d*) Thuringite.
19. *Hýdroférrálucálcimagnésic silicates.* (*a*) Palagonite.
20. *Hýdroférrichrómic silicates.* (*a*) Wolchonskoite; (*b*) Chromochre.
21. *Hýdroférrimagnalumínic silicates.* Ripidolite.
22. *Hýdroférrimágnemangánic silicates.* (*a*) Cronstedtite.
23. *Hýdromagnésic silicates.* (*a*) Villarsite; (*b*) Talc; (*c*) Meerschaum; (*d*) Picrosmine; (*e*) Serpentine; (*f*) Schiller spar.
24. *Hýdromágnesálumínic silicates.* (*a*) Saponite; (*b*) Kammererite; (*c*) Clinochlore.
25. *Hýdromágnesáluférric silicates.* (*a*) Pennine.
26. *Hýdromagnésiférric silicates.* (*a*) Baltímorite.
27. *Hýdronickelálumagnésic silicate.* (*a*) Pimelite.
28. *Hýdrothóric silicates.* (*a*) Thorite.
29. *Hýdrozíncic silicates.* (*a*) Calamine.
30. *Hýdrozircónic silicates.* (*a*) Malacone.
31. *Hýdrozircosódicálcic silicates.* (*a*) Catapleïte.

L.

1. *Lánthanýttrálucálciférric silicates.* (*a*) Orthite.

M.

1. *Magnésic silicates.* (*a*) Peridot; (*b*) Chrysolite; (*c*) Forsterite; (*d*) Tephroite; (*e*) Eustatite; (*f*) Chladnite; (*g*) Steatite.
2. *Magnálupotássiférric silicates.* (*a*) Mica.
3. *Magnésicálcic silicates.* (*a*) Sahlite; (*b*) Tremolite; (*c*) Asbestus; (*d*) Actinote; (*e*) Hornblende; (*f*) Pargasite.
4. *Mágnécálcialumínic silicates.* (*a*) Bucklandite.

4a. *Magnésicálciférric silicates.* (*a*) Hornblende.

5. *Magnésiférric silicates.* (*a*) Hypersthene; (*b*) Diaclasite; (*c*) Anthophyllite.
6. *Magnésifluóric silicates.* (*a*) Chondrodite; (*b*) Humite.
7. *Mágnetitániférric silicates.* (*a*) Titaniferous peridot.
8. *Mangáluminic silicates.* (*a*) Spessartine.
9. *Mangánicálcic silicates.* (*a*) Rhodonite.
10. *Mangániférric silicates.* (*a*) Stratopeite.
11. *Mangániglúciférric silicates.* (*a*) Helvine.

P.

1. *Pótassáluminic silicates.* (*a*) Amphigene.

S.

1. *Stánnic silicate.* (*a*) Cassiterite.
2. *Sódazircocálciférric silicate.* (*a*) Eudialyte.

T.

1. *Titánicálcic silicates.* (*a*) Keilhauite; (*b*) Tschefkinite.

Y.

1. *Yttroférricérelanthánic silicates.* (*a*) Gadolinite.
2. *Yttroférricéráluláncálcimagnésic silicate.* (*a*) Bodenite.

Z.

1. *Zincic silicate.* (*a*) Willemite.
2. *Zircónic silicates.* (*a*) Zircon.

Table XVII. of Typical Mineral Combinations.*

1. ALUMINIUM.—(*a*) With Oxygen: *Sapphire, Corundum, Ruby.*
   (*β*) ,, Water: *Diaspore, Gibbsite, Plumbogummite.*
   (*γ*) With Fluorine and Soda: *Cryolite, Chiolite* (NO SODA), *Topaz.*
   (*δ*) ,, Sulphuric Acid: *Aluminite, Alunite, Lowigite, Kalonite, Mendozite, Tschermigite, Pickeringite, Apjohnite, Bosjemanite, Halotrichite, Copiapite, Voltaite.*
   (*ε*) ,, Phosphoric Acid: *Turquoise, Wavellite, Attacolite, Childrenite, Cirrolite, Peganite, Fischerite, Tavistockite, Augelite, Amblygonite, Lazulite, Calainite, Barrandite, Plumboresinite.*
   (*ζ*) ,, Silicic Acid: *Cyanite, Andalusite, Sillimanite, Staurolite, Orthoclase, Tourmaline, &c.*
   (*η*) ,, Silica and Water: *Pholerite, Meerschaluminite, Allophane, Kaolin, Pyrophillite.*
   (*θ*) ,, Silica and Fluorine: *Topaz, Pyonite.*
   (*ι*) ,, Lead: *Plumbogummite.*

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* By this term is here to be understood a combination either chemical or mechanical.

(κ) With Iron: *Emery.*
(λ) ,, Mellitic Acid: *Mellite.*
(μ) Aluminates: *Spinel, Hercynite, Gahnite.*

2. ANTIMONY.—(α) Metallic: *Native Antimony.*
(β) With Oxygen: *Valentinite*
(γ) ,, Nickel: *Breithauptite, Ullmannite.* With Lime and Iron: *Cervantite.*
(δ) ,, Arsenic: *Allemontite, Ullmannite.*
(ε) ,, Silver: *Dyscrasite, Proustite, Pyrargyrite, Stephanite, Polybasite, Miargyrite.*
(ζ) ,, Sulphur: *Stibnite, Berthierite, Zinkenite, Plagionite, Meneghinite, Steinmannite.*
(η) ,, Copper: *Bournonite, Tetrahedrite, Sandbergerite, Chalcostibnite.*
(θ) ,, Lead: *Jamesonite, Berthierite, Boulangerite, Heteromorphite, Plagionite, Zinkenite.*

3. ARSENIC.—(α) Metallic: *Native Arsenic,* often containing traces of Bismuth, &c.
(β) With Antimony: *Allemontite, Ullmannite.*
(γ) ,, Oxygen: *Arsenolite.* With Copper: *Domeykite, Algodonite, Whitneyite.*
(δ) ,, Sulphur: *Realgar, Orpiment.*
(ε) ,, Cobalt Nickel, &c.: *Smaltite, Millerite, Jeypoorite, Niccolite.*
(ζ) ,, Manganese: *Kaneite.*
(η) ,, Silver: *Proustite.*
(θ) As Acid with Base: *Erythrite, Annabergite.*

4. BARIUM.—(α) With Sulphuric Acid: *Barite, Barytocelestite, Dreelite.*
(β) With Carbonic Acid: *Witherite, Barytocalcite, Bromlite.*
(γ) ,, Silicic Acid: *Harmotome, Brewsterite.*
(δ) ,, Manganese: *Psilomelane, Braunite, Hausmannite.*

5. BISMUTH.—(α) Metallic: *Native Bismuth.*
(β) With Tellurium or Selenium: *Tetradymite, Joseite, Wehrlite.*
(γ) ,, Silver: *Chilenite.*
(δ) ,, Sulphur: *Bismuthinite, Karelinite.*
(ε) ,, Copper: *Emplectite, Annivite.*
(ζ) ,, Lead: *Chiviatite, Kobellite.*
(η) ,, Nickel: *Grünanite, Rammelsbergite.*
(θ) ,, Oxygen: *Bismuthochre, Karelinite.*
(ι) ,, Carbonic Acid: *Bismuthite.*
(κ) ,, Phosphoric Acid: *Hypochlorite.*

6. BORON.—(α) With Water: *Sassoline.*
(β) With Soda: *Borax.*
(γ) ,, Ammonia: *Larderellite.*
(δ) ,, Magnesia: *Boracite.*
(ε) ,, Lime: *Borocalcite, Hydroboracite.*
(ζ) ,, Silica: *Tourmaline, Axinite, Datholite.*

7. CADMIUM.—(α) With Sulphur: *Greenockite, Sphalerite.*
(β) With Oxygen: *Calamine.*

8. Calcium.—(*a*) With Chlorine: *Tachhydrite.*
(*β*) With Fluorine: *Fluor Spar, Prosopite Yttrocerite.*
(*γ*) ,, Sulphuric Acid: *Gypsum, Anhydrite, Polyhalite.*
(*δ*) ,, Nitric Acid: *Nitrocalcite.*
(*ε*) ,, Phosphoric Acid: *Apatite, Francolite, Pyromorphite, Kunkur.*
(*ζ*) ,, Carbonic Acid: *Calcite, Aragonite, Dolomite.*
(*η*) ,, Oxalic Acid: *Whewellite.*
(*θ*) ,, Boric Acid: *Hayesine.*
(*ι*) ,, Arsenic Acid: *Pharmacolite, Kühnite.*
(*κ*) ,, Tungstic Acid: *Scheelite.*
(*λ*) ,, Antimonious Acid: *Roméite.*
(*μ*) ,, Columbic Acid: *Pyrochlore.*
(*ν*) ,, Titanic Acid: *Perowskite.*
(*ξ*) ,, Silicic Acid: *Wollastonite, Augite, Scapolite, Phrenhite.*

9. Cerium, Lanthanum, Didymium.—(*a*) With Fluorine: *Fluocerite, Yttrocerite.*
(*β*) With Phosphoric Acid: *Cryptolite, Monazite.*
(*γ*) ,, Carbonic Acid: *Parisite, Lanthanite.*
(*δ*) ,, Tantalic Acid: *Fergusonite.*
(*ε*) ,, Titanic and Columbic Acid: *Euxenite.*
(*ζ*) ,, Silicic Acid: *Cerite, Allanite, Orthite.*
(*η*) ,, Silicic and Titanic Acid: *Tschewkinite, Mosandrite.*

10. Chromium.—(*a*) Metallic: In *Meteoric Iron* sometimes.
(*β*) With Oxygen and Iron: *Chromite.*
(*γ*) ,, Alumina: *Chrome Ochre, Walchonsköite.*
(*δ*) ,, Lime: *Ouvarovite.*
(*ε*) ,, Potash and Soda: *Fuchsite.*
(*ζ*) ,, Magnesia: *Spinel.*
(*η*) ,, Glucina: *Chrysoberyl.*
(*θ*) As Chromic Acid: *Vauquelinite, Melanchroite.*

11. Cobalt.—(*a*) With Arsenic and Iron: *Smaltite, Skutterudite.*
(*β*) With Sulphur and Arsenic: *Cobaltite, Jeypoorite, Linnæite, Carrolite.*
(*γ*) ,, Nickel: *Siegenite, Grünanite, Linnæite, Carrolite.*
(*δ*) ,, Selenium: *Tilkerodite.*
(*ε*) ,, Manganese: *Asbolane.*
(*ζ*) ,, Sulphuric Acid: *Bieberite.*
(*η*) ,, Arsenic Acid: *Erythrine.*

12. Copper.—(*a*) Metallic: *Native Copper.*
(*β*) With Arsenic: *Darwinite, Domeykite, Condurrite.*
(*γ*) ,, Selenium: *Berzelianite, Eucairite.*
(*δ*) ,, Sulphur and Iron: *Chalcocite, Bornite, Chalcopyrite, Boulangerite, Cubanite, Barnhardite.*
(*ε*) ,, Zinc, Silver, Mercury, Antimony, &c.: *Tetrahedrite, Castillite.*
(*ζ*) ,, Bismuth: *Wittichite.*
(*η*) ,, Silver: *Jalpaite, Polybasite, Stromeyerite.*
(*θ*) ,, Cobalt: *Carollite.*
(*ι*) ,, Antimony, &c.: *Wölchite.*

(κ) With Lead: *Bournonite, Alisonite.*
(λ) „ Chlorine: *Atacamite, Percylite.*
(μ) „ Sulphuric Acid: *Cyanosite.*
(ν) „ Phosphoric Acid: *Liebethenite, Thrombolite, Turquoise.*
(ξ) „ Carbonic Acid: *Malachite, Chessylite.*
(ο) „ Arsenic Acid: *Olivenite, Chalcophyllite.*
(π) „ Chromic Acid: *Vauquelinite.*
(ρ) „ Vanadic Acid: *Volborthite.*
(σ) „ Silicic Acid: *Dioptase, Chrysocolla, Allophane.*

13. **Didymium.**—See 9.

14. **Erbium.**—(*a*) With Yttria: *Orthite, Gadolinite.*

15. **Fluorine.**—(*a*) With Lime: *Fluor Spar, Aragonite.*
(β) With Soda: *Cryolite.*
(γ) „ Lithia: *Amblygonite.*
(δ) „ Yttria and Ceria: *Yttrocerite, Parisite.*
(ε) „ Magnesia: *Wagnerite, Chondrodite, Humite.*
(ζ) „ Alumina: *Topaz.*

16. **Glucinum.**—(*a*) With Silica: *Beryl.*
(β) With Lime and Magnesia: *Phenakite.*
(γ) „ Tin and Iron: *Euclase.*
(δ) „ Chromium (?): *Emerald.*
(ε) „ Yttria: *Gadolinite.*
(ζ) „ Manganese and Sulphur: *Helvine.*
(η) „ Soda and Potash: *Leucophane.*
(θ) „ Alumina: *Chrysoberyl.*

17. **Gold.**—(*a*) Metallic: *Native Gold.*
(β) With Palladium: *Porpezite.*
(γ) „ Rhodium: *Rhodium Gold, Mexico.*
(δ) „ Tellurium: *Sylvanite.*
(ε) „ Antimony: *Gelberz.*
(ζ) „ Lead, Copper, and Sulphur: *Nagyagite.*

18. **Iridium.**—(*a*) With Osmium, Rhodium, &c.: *Iridosmine.*

19. **Iron.**—(*a*) Metallic: *Meteorites, Native,* with *Graphite.*
(β) With Arsenic: *Mispickel, Scorodite, Pharmacosiderite.*
(γ) „ Sulphur: *Pyrite, Chalcopyrite, Kyrosite.*
(δ) „ Oxygen: *Magnetite, Hematite, Gothite.*
(ε) „ Magnesia: *Magneferrite, Cronstedtite.*
(ζ) „ Manganese and Zinc: *Franklinite.*
(η) „ Chromium: *Chrome Iron.*
(θ) „ Chlorine: *Kremersite.*
(ι) „ Sulphuric Acid: *Copperas.*
(κ) „ Phosphoric Acid: *Vivianite, Childrenite.*
(λ) „ Carbonic Acid: *Chalybite, Humboldtite.*
(μ) „ Boric Acid: *Lagonite.*
(ν) „ Tungstic Acid: *Wolframite.*
(ξ) „ Titanic Acid: *Ilmenite, Kibdelophane.*
(ο) „ Tantalic Acid: *Tantalite.*

(π) With Niobic Acid: *Columbite.*
(ρ) ,, Silica: *Garnet* (iron), *Nontronite*, *Anthosiderite.*
(σ) ,, Copper: *Chalcopyrite*, *Boulangerite.*
,, Silver: *Sternbergite.*

20. LEAD.—(α) With Tellurium: *Altaite.*
(β) With Gold and Silver: *Sylvanite*, *Nagyagite.*
(γ) ,, Selenium: *Clausthalite*, *Berzelianite.*
(δ) ,, Sulphur: *Galena*, *Steinmannite*, *Caledonite.*
(ε) ,, Chlorine: *Mendipite*, *Matlockite*, *Percylite.*
(ζ) ,, Oxygen: *Plumbic Ochre*, *Plattnerite.*
(η) ,, Phosphoric Acid: *Pyromorphite*, *Plumboresinite.*
(θ) ,, Arsenic Acid: *Mimetite*, *Carmine Spar.*
(ι) ,, Carbonic Acid: *Cerusite*, *Tarnowitzite.*
(κ) ,, Lime: *Plumbocalcite.*
(λ) ,, Zinc: *Zinc lead spar.*
(μ) ,, Chromic Acid: *Melanochriote*, *Vauquelinite.*
(ν) ,, Vanadic Acid: *Vanadinite*, *Descloizite.*
(ξ) ,, Molybdic Acid: *Wülfenite.*
(ο) ,, Tungstic Acid: *Scheelite.*
(π) ,, Antimony: *Jamesonite*, *Boulangerite*, *Bleinierite.*
(ρ) ,, Copper: *Bournonite*, *Cuproplumbite.*

21. LITHIUM.—(α) With Phosphoric Acid: *Amblygonite*, *Triphylline.*
(β) With Silica and Alumina: *Spodumen*, *Petalite.*
(γ) ,, Potash: *Lepidolite.*
(δ) ,, Lime: *Scapolite.*

22. MAGNESIUM.—(α) With Chlorine: *Tachydrite.*
(β) With Sulphuric Acid: *Epsomite*, *Martinsite.*
(γ) ,, Phosphoric Acid: *Wagnerite*, *Lazulite*, *Sordawalite.*
(δ) ,, Carbonic Acid: *Magnesite*, *Breunnerite.*
(ε) ,, Boric Acid: *Boracite*, *Stassfurthite.*
(ζ) ,, Arsenic Acid: *Picropharmacolite*, *Kuhnite.*
(η) ,, Silica: *Talc*, *Sepiolite*, *Tourmaline*, *Serpentine.*
(θ) ,, Fluorine: *Chondrodite.*
(ι) ,, Alumina: *Spinel*, *Pleonaste.*

23. MANGANESE.—(α) With Arsenic: *Kaneite.*
(β) With Sulphur: *Alabandite*, *Hauerite.*
(γ) ,, Oxygen: *Pyrolusite*, *Psilomelane*, *Hausmanite.*
(δ) ,, Carbonic Acid: *Diallogite*, *Manganocalcite.*
(ε) ,, Tungstic Acid: *Wolframite.*
(ζ) ,, Tantalic and Niobic Acid: *Tantalite*, *Columbite.*
(η) ,, Silica, Alumina, Glucina, &c.: *Rhodonite*, *Helvine*, *Carpholite.*
(θ) ,, Zinc and Iron: *Franklinite.*
(ι) ,, Phosphoric Acid: *Triplite.*

24. MERCURY.—(α) With Selenium and Lead, &c.: *Onofrite*, *Therbachite*, *Tiemannite.*
(β) With Sulphur: *Cinnabar*, *Hepatic Cinnabar.*
(γ) ,, Copper and Silver: *Spaniolite.*
(δ) ,, Chlorine: *Calomel* (Bavaria).
(ε) ,, Iodine: *Coccinite.*
(ζ) ,, Selenium: *Tiemannite.*

25. Molybdenum.—(a) With Sulphur: *Molybdenite.*
(β) With Oxygen: *Molybdite.*
(γ) „ Lead: *Wülfenite.*

26. Nickel.—(a) With Antimony: *Briethauptite.*
(β) With Arsenic: *Niccolite (Copper Nickel), Chloanthite.*
(γ) „ Sulphur: *Millerite, Troilite.*
(δ) „ Bismuth: *Grünauite.*
(ε) „ Iron: *Pentlandite, Troilite, Pyrrhotite.*
(ζ) „ Cobalt and Copper: *Smaltite, Cobaltite.*
(η) „ Oxygen: *Pimelite.*
(θ) „ Carbonic Acid: *Emerald Nickel.*
(ι) „ Silica, Magnesia, and Iron: *Chrysolite, Röttisite.*

27. Niobium.—(a) With Iron, Manganese, and Tantalic Acid: *Columbite.*

28. Osmium.—(a) With Iridium, Rhodium, &c.: *Iridosmine.*

29. Platinum.—(a) With Iridium and Copper: *Platiniridium.*

30. Potassium.—(a) With Chlorine: *Sylvine, Carnallite.*
(β) With Sulphuric Acid: *Alunite, Polyhalite, Voltaite.*
(γ) „ Nitric Acid: *Nitre.*
(δ) „ Silica: *Orthoclase, Hyalophane, Mica, Apophyllite.*
(ε) „ Manganese: *Gigantolite, Psilomelane.*
(ζ) „ Magnesia: *Villarsite, Obsidian, Pumice stone.*
(η) „ Lime: *Stilbite, Palagonite, Apophyllite:*
(θ) „ Soda: *Albite, Eudialite, Lava.*

31. Rhodium.—(a) With Iridium, Osmium, &c.: *Iridosmine.*

32. Selenium.—(a) With Lead, Copper, Thallium, &c.: *Clausthalite, Berzelianite, Crookesite, Zorgite.*
(β) With Mercury: *Onofrite, Tiemannite, Lehrbachite.*
(γ) „ Tellurium: *Tetradymite.*

33. Silver.—(a) With Gold: *Native Gold.*
(β) With Bismuth: *Bismuth Silver.*
(γ) „ Mercury: *Native Amalgam.*
(δ) „ Antimony: *Pyrargyrite, Discrasite, Stephanite.*
(ε) „ Tellurium: *Nagyagite, Sylvanite, Hessite.*
(ζ) „ Selenium: *Eucairite, Naumannite.*
(η) „ Sulphur: *Argentite, Daleminzite, Acanthite.*
(θ) „ Bromine and Iodine: *Bromyrite, Iodyrite.*
(ι) „ Chlorine: *Kerargyrite.*
(κ) „ Arsenic: *Proustite.*
(λ) „ Iron: *Sternbergite.*

34. Sodium.—(a) With Chlorine: *Common Salt, Sodalite, Eudialite.*
(β) With Fluorine and Alumina: *Cryolite, Soda, Alum, Chiolite.*
(γ) „ Sulphuric Acid: *Glauber Salt, Thenardite.*
(δ) „ Lime: *Glauberite, Analcime, Gay-Lussite, Natrolite.*
(ε) „ Nitric Acid: *Nitratine.*
(ζ) „ Carbonic Acid: *Natron, Cancrinite.*
(η) „ Boric Acid: *Borax, Hayesine.*
(θ) „ Silica, Iron, &c.: *Albite, Achmite, Arfvedsonite.*

35. **Strontium.**—(*a*) With Sulphur: *Celestine.*
(β) With Carbonic Acid: *Strontianite.*
(γ) ,, Silica: *Brewsterite.*

36. **Tantalum Columbium.**—(*a*) With Iron: *Tantalite, Wolframite, Columbite.*
(β) With Lime: *Pyrochlore.*
(γ) ,, Yttria: *Yttrotantalite, Lamarskite, Fergusonite.*
(δ) ,, Zirconia: *Wöhlerite, Eukolite.*

37. **Tellurium.**—(*a*) With Gold and Silver: *Sylvanite, Nagyagite.*
(β) With Lead: *Altaite.*

38. **Thorium.**—(*a*) With Lime: *Pyrochlore.*
(β) With Yttria: *Lamarskite.*
(γ) ,, Silica: *Thorite, Orangite.*

39. **Tin.**—(*a*) With Sulphur: *Stannite.*
(β) With Oxygen: *Cassiterite.*

40. **Titanium.**—(*a*) With Oxygen: *Rutile, Brookite, Anatase.*
(β) With Lime: *Schorlomite, Sphene, Perowskite.*
(γ) ,, Yttria: *Polycrase, Euxenite, Yttrotitanite.*
(δ) ,, Zirconia: *Œrstedlite.*
(ε) ,, Ceria, &c.: *Mosandrite, Tschewkinite.*
(ζ) ,, Iron: *Ilmenite, Iserine.*

41. **Tungsten.**—(*a*) With Oxygen: *Tungstite.*
(β) With Lime: *Scheelite.*
(γ) ,, Lead: *Scheeletite.*
(δ) ,, Iron: *Wolframite.*
(ε) ,, Yttria; *Lamarskite, Yttrotantalite.*
(ζ) ,, Tantalic and Niobic Acid: *Columbite, Tantalite.*

42. **Uranium.**—(*a*) With Sulphuric Acid: *Trippeite, Johannite.*
(β) With Iron, Silica, Lime, Lead, &c.: *Pitchblende.*
(γ) ,, Phosphoric Acid: *Uranite.*
(δ) ,, Carbonic Acid: *Liebigite, Voglite.*
(ε) ,, Silica: *Uranophane.*

43. **Vanadium.**—(*a*) With Lead: *Vanadinite.*

44. **Yttrium.**—(*a*) With Silica, Glucina, and Iron: *Gadolinite.*

45. **Zinc.**—(*a*) With Sulphur: *Sphalerite, Przibram Galena, Voltzite.*
(β) With Manganese and Iron: *Franklinite.*
(γ) ,, Carbonic Acid: *Calamine, Aurichalcite.*
(δ) ,, Silica: *Smithsonite.*

46. **Zirconium.**—(*a*) With Silica: *Zircon.*

[The analyst may use this Table (at least) in two ways. He may form a typical mineral *cabinet* from it, in conjunction with the Tables given in pages 175, 185, of this work, for which purpose I can honestly recommend the establishment of Mr. Henson, the mineralogist, of the Strand, London; or he may analyze any of the minerals given, with the view of detecting the typical *elements* here indicated.]

Table XVIII.—Of the Commoner Colours of some Minerals.

Minerals.	Colours, according to Werner and Jameson.	Animal Kingdom.	Vegetable Kingdom.
1. *Agalmatolite*	Rose Red	Flamingo	Garden Rose
2. *Amethyst*	Violet Purple	Neck of Humming Bird. *Calliphlox Amethystina.*	Purple Aster
3. *Asbolane*	Bluish Black	Largest Black Slug	Cowberry
4. *Aragonite*	Purplish White	Neck of Kittiwake Gull	White Geranium
5. *Axinite*	Clove Brown	Neck of Male Kestril	Stems of Black Currant
6. *Barite*	Flesh Red	Human Skin	Larkspur
7. *Basalt*	Greyish Black	Breast of Water Ouzel	Black Hyacinth
8. *Beryl*	Asparagus Green	Brimstone Butterfly	Horse-shoe Geranium
9. ,,	Oil Green	Shell of Water Snail	Nonpareil Apple
10. *Blende*	Deep Reddish Brown	Neck of Teal (Drake)	Dead Leaves
11. ,,	Yellowish Brown	Breast of Hoopoe.	
12. *Calamine*	Straw Yellow	Polar Bear	Oat Straw
13. *Calc Sinter*	Greenish White	Vent-coverts of the G. C. Wren	Polyanthus Narcissus
14. *Carrara Marble*	Snow White	Breast of the Gull	Snowdrop
15. *Ceylanite*	Duck Green	Neck of the Mallard	Yew Leaves
16. *Chalcedony*	Yellowish Grey	Vent-coverts of White-rump	Stems of the Barberry
17. *Chalk*	Yellowish White	Egret	Hawthorn Blossom
18. *Chessylite*	China Blue	Rhynchites Nitens	Back part of Gentian Flower
19. *Chrysolite*	Pistachio Green	Neck of Eider Drake	Hypnum-like Saxifrage
20. *Cinnabar*	Scarlet Red	Scarlet Ibis	Red Oriental Poppy
21. ,,	Vermilion Red	Red Coral	Love Apple
22. *Clay Slate*	Greenish Grey	Quill-feathers of Robin	Bark of Ash Tree
23. *Egyptian Jasper*	Chestnut Brown	Breast of Red Grouse	Chestnuts
24. *Epidote*	Olive Green	Indian Paroquet	Lignum Vitæ
25. *Erubescite* (*Bornite*)	Scotch Blue	Throat of Blue Titmouse	Stamen of Purple Anemone
26. ,,	Prussian Blue	Wing Spot of Mallard	Stamen of Blue Anemone
27. ,,	Indigo Blue	. . . .	Stamen of Violet
28. ,,	Azure Blue	Breast of Green Cr. Manakin	Grape-hyacinth Gentian
29. ,,	Flax-flower Blue	Wings of Devil's Butterfly	Flower of Flax

Table XVIII.—(*continued*).

Minerals.	Colours, according to Werner and Jameson.	Animal Kingdom.	Vegetable Kingdom.
30. *Erythrine*	Peach-blossom Red	Legs of Flamingo	Peach Blossom
31. *Flint*	Ash Grey	Breast of long-tail Titmouse	Fresh Wood Ashes
32. ,,	Smoke Grey	Grey part, Breast of Robin.	
33. ,,	Blackish Grey	Back of Nuthatch	Old stems of Hawthorn
34. *Fluor*	Pansy Purple	Chrysomela Goettingensis	Sweet-scented Violet
35. ,,	Campanila Purple	Neck of Pigeon	Canterbury Bell
36. ,,	Imperial Purple	Neck of Impeyan Pheasant	Parts of Saffron Crocus
37. ,,	Auricula Purple	Egg of largest Bluebottle Fly	Purple Auricula
38. ,,	Plum Purple	Breast of Tragopan	Plum
39. ,,	Honey Yellow	Gallstones	Marigold Apple
40. *French Chalk*	Orange-coloured White	Breast of Screech Owl	Large Wild Convolvulus
41. *Garnet*	Crimson Red	Breast of Macaw	Crimson Peony
42. ,,	Purplish Red	Outside of quills of Terico	Officinal Garden Rose
43. *Granular Limestone*	Greyish White	Inside of quill-feathers of Gull	White Hamburg Grapes
44. *Hepatic Cinabar*	Cochineal Red	Coccus Cacti	Decayed Leaf of "None-so-pretty"
45. *Hornblende*	Greenish Black	Breast of Lapwing	Black Tulip
46. *Hyacinth*	Hyacinth Red	Spots of Lygæus Apterus	Red on the Golden Rennet
47. *Iron Earth*	Greyish Blue	Back of Blue Titmouse	Small Fennel Flower
48. *Iron Flint*	Brownish Red	Red on Red-throated Diver	Wallflower
49. ,,	Umber Brown	Moor Buzzard	Disk of Rubeckia
50. *Jasper*	Lavender Purple	Under-spots, Peacock Butterfly	Dried Lavender
51. ,,	Pale Bluish Purple		Pale purple Hyacinth
52. ,,	Tile Red	Breast of Cock Bullfinch	Shrubby Pimpernel
53. ,,	Ochre Yellow	Vent-coverts of Redstart	Buttercup
54. ,,	Cream Yellow	Breast of Teal (Drake)	Stephanotis
55. ,,	Orange-coloured Brown	Wing-coverts of Sheldrake	Female Spike of Catstail
56. *Kermesite*	Brownish Purple Red		Flower of Deadly Nightshade
57. *Lapis Lazuli*	Ultramarine Blue	Wings of Heath Butterfly	Borrage
58. *Lenticular Ore* (*Liroonite*)	Verditter Blue.		

59. *Lepidolite*	Bluish Lilac Purple	Lebellula Depressa (Male)	Blue Lilac
60. ,,	Red Lilac Purple	Spots, Peacock Butterfly	Purple Primrose
61. *Liverite*	Brownish Black	Wing-coverts of Black Cock	Dark Wallflower
62. *Lias Limestone*	Bluish Grey	Tail-coverts of Wood Pigeon	,, Hyacinth
63. *Mineral Tar (Petroleum)*	Blackish Brown	Stormy Petrel	Brown Calceolaria
64. *Mountain Wood (Asbestos)*	Wood Brown	Common Weasel	Hazel Nuts
65. *Natrolite*	Buff Orange	Streak on eye of Kingfisher	Stamen of White Cistus
66. *Obsidian*	Velvet Black	Mole	Black of Indian Sweet Pea
67. *Olivenite*	Reddish Black	Breast of Pochard Duck	Berry, Fuchsia Coccinea
68. ,,	Ink Black	Breast of Black Partridge	Berry, Deadly Nightshade
69. *Opal*	Bluish White	White of human eyeballs	Petals, Blue Hepatica
70. *Orpiment*	Lemon Yellow	Large Wasp or Hornet	Shrubby Goldilocks
71. ,,	Dutch Orange	Golden-crested Wren	Common Marigold
72. ,,	Aurora Red	Vent-coverts of Pied Woodpecker	Red on the Apple
73. *Porcelain Jasper*	Pearl Grey	Back of Kittiwake	Petals, Purple Hepatica
74. *Porcelain Spar*	Reddish White	Egg of Grey Linnet	Back of Christmas Rose
75. *Pyrope*	Venous Blood Red	Venous Blood	Dark Purple Scabious
76. *Ruby Oriental*	Carmine Red	Cochineal	Raspberry
77. *Ruby Spinel*	Lake Red		Petals of Peony
78. *Sapphire*	Berlin Blue	Wing-feathers of Jay	Hepatica
79. *Semi-Opal*	Wax Yellow	Larva of large Water Beetle	Nonpareil Apple
80. ,,	Liver Brown	Wing-coverts of Grosbeak	Brown Wallflower
81. *Sulphur*	Sulphur Yellow	Yellow parts of large Dragonfly	Vari-coloured Snapdragon
82. ,,	Primrose Yellow	Pale Canary Bird	Wild Primrose
83. ,,	Gamboge Yellow	Wings of Goldfinch	Yellow Jasmine
84. *Topaz*	Brownish Orange	Eyes of large Flesh Fly	Style of Orange Lily
85. ,,	Wine Yellow	Body of Silk Moth	White Currants
86. ,,	Sienna Yellow	Tail, Bird of Paradise	Stamen of Honeysuckle
87. *Turquoise*	Greenish Blue	Indian Roller	Great Fennel Flower
88. *Uranite*	Siskin Green	Siskin	Ripe Coalmar Pear
89. ,,	Grass Green	Scarabæus Nobilis	Fresh Grass
90. *Wood Tin*	Hair Brown	Head of Pintail Duck	Bark of Elm-tree
91. *Zircon*	Broccoli Brown	Head of Black-headed Gull.	

Table XIX.—Average per Cent. Composition of some Normal Schistose Rocks.*

Rock.	Spec. Grav.	Silica.	Alumina.	Iron perox.	Iron protox.	Mangan. protox.	Lime.	Magnesia.	Potash.	Soda.	Water.
Talc Schist . .	..	50·—58·	4·5—9·	3·5—7·	1·0	..	1·—1·5	23·—31·5	..	..	0·—6·
Chlorite Schist .	2·7—2·9	42·—45·	3·—14·	0·—4·5	9·—27·	0·5	0·2—1·5	8·—17·	0·6	0·2—1·5	4·5—11·2
Hornblende Schist	3·—3·1	48·—50·	13·3—16·4	12·—27·5	4·5—9·	0·—0·5	0·6—12·	2·—2·6	0·5—1·2	1·9—2·3	..
Hornblende Rock .	2·94	49·42	18·12	5·—41·	9·60	..	8·65	3·16	1·27	2·57	1·80 (loss)
Clay Slate . .	2·6—2·9	54·—64·	13·—23·	0·—19·	0·—8·5	..	0·5—9	1·—9·5	1·—6·	1·—3·9	0·—3·9
,, Alum Slate .	2·42	52·28	16·64	(FeS_2) 7·74	6·96	..	1·53	1·10	7·98	(Carbon) 4·37	1·40 (loss)
Mica Schist . .	2·77	65·13	18·16	..	5·27	0·51	0·32	2·70	2·99	0·53	(TiO_2) 1·54
Mica Gneiss .	2·70	65·—75·	13·—21·	0·—5·8	0·—6·	0·—0·5	1·—5·	0·5—3·	1·5—4·8	0·5—2·5	..
Hornblende Gneiss	2·80	56·83	19·68	2·88	5·76	trace	1·80	3·28	3·14	2·34	(TiO_2) 0 47 (CuO) 0·09
Granulite . .	2·66	73·47	14·86	..	3·28	..	1·62	0·67	3·95	1·80	(H_2O) 0·57

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* "Text-Book of Geology," Prof. A. Geikie, LL.D., F.R.S., 1882, page 126.

Table XX.—Average per Cent. Composition of the chief Triclinic Felspars.*

Felspar.	Silica.	Alumina.	Potash.	Soda.	Lime.	Hardness.	Sp. Gr.	Habitat.
Microcline . .	64·30	19·70	15·60	0·48	..	6·0	2·540	In some Syenites, &c.
Albite . . .	68·62	19·56	..	11·82	..	6·—6·5	2·5—2·6	In some Granites, and in several Volcanic Rocks.
Oligoclase . .	63·70	23·95	1·20	8·11	2·05	6·0	2·6—2·7	In many Granites, and other Eruptive Rocks.
Andesine . . .	63·85	24·05	0·88	5·04	5·04	5·—6·	2·6—2·7	In some Syenites, &c.
Labradorite . .	52·90	30·30	..	4·50	12·30	6·0	2·7—2·74	Essential constituent of many Lavas, &c.; abundant in masses in Azoic Rocks of Canada, &c.
Anorthite. . .	43·08	36·82	..	..	20·10	6·0	2·7—2·76	In many Volcanic Rocks; sometimes in Granites, and Metamorphic Rocks.

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* "Text-Book of Geology," Prof. A. Geikie, LL.D., F.R.S., 1882, page 72.

The student who wishes further information in this matter will find detailed reactions of every metal, &c., arranged with a view to facility of reference, in my "Alphabetical Manual of Blowpipe Analysis." Trübner & Co. 1880.

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Ross's Air Reservoir Blowpipe, with platinum nozzle (Fig. 3)		0	5	0
,, ,, with brass nozzle		0	3	0
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Air Reservoirs	per doz.	0	0	6
Nozzles, brass, 4d.; platinum, 2s. each	4d. to	0	2	0
Ross's Pyrological Candles, 5d. each	per lb.	0	1	6
Ross's Pyrological Candle Lamp (Fig. 16)		0	4	6
Berzelius Lamp (Oil), on stand, with folding stand (Fig. 14)		0	8	6
Grease Lamp, as in Society of Arts cases		0	0	10
Wick for Lamps	per yard	0	0	3
Spirit Lamps, tin or glass	each from	0	1	0
Hand Bellows, Ross's, leather (Fig. 10)		0	3	6
„ Letcher's, vulcanite		0	2	6
Ross's Aluminium Plates (Fig. 25), by weight at market price.				
Letcher's Universal Motion Blowpipe Stand	each	0	4	6
„ „ Holder	each	0	4	6
Charcoal Saws	each from 6d. to	0	1	0
Ross's Steel Anvil Mortar (Figs. 58, 60), well made		0	3	6
Platinum Forceps (Fig. 32)	each 3s. to	0	3	6
latinum Wire, per inch, 1d.	per oz.	1	16	0
Agate Slabs (Fig. 56). Quotations per size.				
Pliers, forming horseshoe magnet (Fig. 41),	from 1s. 6d. to	0	2	6
Pliers, ordinary	from 1s. to	0	3	6
Porcelain Boiling Dishes	from 3d. to	0	1	0
Holders for Dishes, &c. (Fig. 64)	each	0	0	4
Test-Tube Holders (Fig. 31)	each 2d. to	0	0	6
Magnifying Glasses (Figs. 61, 62)	each 1s. to	0	3	6
Knives	each 1s. to	0	3	6
Scissors	each 6d. to	0	3	6
Scissor-Forceps (Fig. 48)	each 1s. 6d. to	0	3	6

Prices of Blowpipe Apparatus—*continued.*

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Blue Glass Slips, each 2d.	per doz.	0	1	6
Closed Tubes (Fig. 29), per doz., 3d.	per gross	0	2	9
Thin Tubing	per lb.	0	1	8
Tube-Combustion (very thin, of the finest quality)	per lb.	0	3	0

REAGENTS.

		£	*s.*	*d.*
Calcium Borate, in bottles	each 8d. to	0	1	0
Cobalt Nitrate, pure	per oz.	0	1	6
Stick Glacial Phosphoric Acid	per oz.	0	0	6
„ „ Pink with cobalt, to test for Alkalies,	per bottle, of beads	0	1	0
Soda Carbonate, pure	per oz.	0	0	3
Potash Carbonate, pure	per oz.	0	0	6
Magnesium Ribbon, 8d. per yard	per oz.	0	13	0
Boric Acid	per oz.	0	0	3
„ in beads fused according to quantity.				
Tunstic Acid	per oz.	0	1	6
Titanic Acid, pure, 8s. per oz. $Ti\,O_2$ (Rutile)	per lb.	0	3	3
Bisulphate of Potash	per oz.	0	0	2
Fluor Spar	per oz.	0	0	2
Litmus Paper, red and blue	per book	0	0	2
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